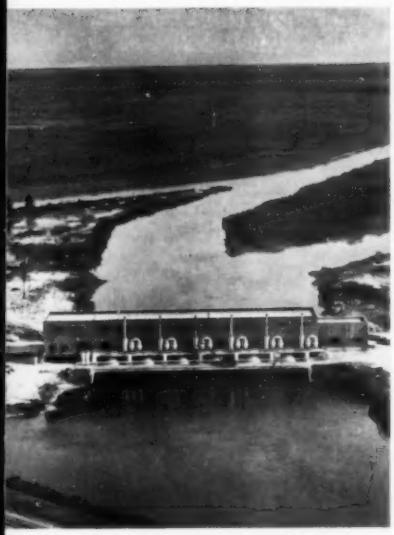
JUNE 1960

Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 52 • NO. 6



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Hurst

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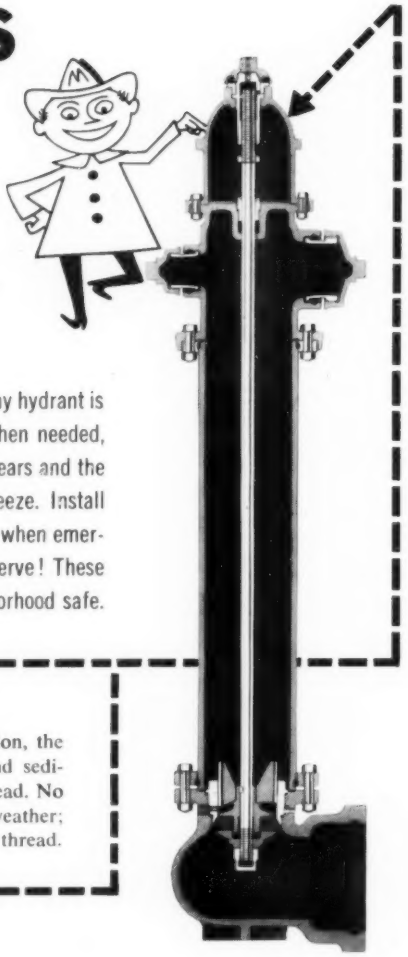
MATHEWS FLANGE BARREL HYDRANT



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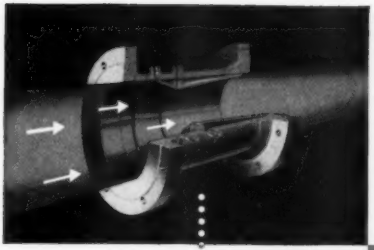

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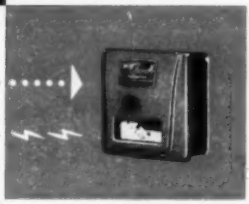

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Coming Meetings

AWWA SECTIONS

Sep. 7–9—South Dakota Section, at Grant Hotel, Watertown. Secretary, J. Darrell Bakken, Div. of San. Eng., State Dept. of Health, Pierre.

Sep. 12–14—Kentucky-Tennessee Section, at Andrew Johnson Hotel, Knoxville, Tenn. Secretary, Harold F. Mount, Gen. Mgr., Preston Street Road Water Dist. No. 1, 5400 Preston Hwy., Louisville, Ky.

Sep. 14–16—Virginia Section, at Cavalier Hotel, Virginia Beach. Secretary, Edward H. Ruehl, R. Stuart Royer & Assoc., 15 W. Cary St., Richmond.

Sep. 14–16—New York Section, at Saranac Inn., Upper Saranac Lake. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 22-22 Jackson Ave., Long Island City 1.

Sep. 21–23—Michigan Section, at Park Place Hotel, Traverse City. Secretary, T. L. Vander Velde, Chief, Section of Water Supply, State Dept. of Health, DeWitt Rd., Lansing.

Sep. 21–23—North Central Section, at Lowry Hotel, St. Paul, Minn. Secretary, Carl A. Flack, Registrar, Water Dept., 216 City Hall, St. Paul, Minn.

Sep. 25–27—Missouri Section, at Governor Hotel, Jefferson City. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Bldg., Jefferson City.

Sep. 28–30—Wisconsin Section, at Loraine Hotel, Madison. Secretary, Harry Breimeister, Bureau of Engineers, 607 Municipal Bldg., Milwaukee.

Sep. 28–30—Canadian Section, Maritime Branch, at Charlottetown Hotel, Charlottetown, P.E.I. Secretary, J. D. Kline, Gen. Mgr., Public Service Com., Halifax, N.S.

Oct. 6—Connecticut Section, at Sanford Barn, Hamden. Secretary, Donald W. Loiselle, Supt. of Supply, Bridgeport Hydraulic Co., Bridgeport.

Oct. 9–12—Alabama-Mississippi Section, at Tutwiler Hotel, Birmingham, Ala. Secretary, Ernest Bryan, McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 16–19—Southwest Section, at Galvez Hotel, Galveston, Tex. Secretary, Leslie A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 19–21—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

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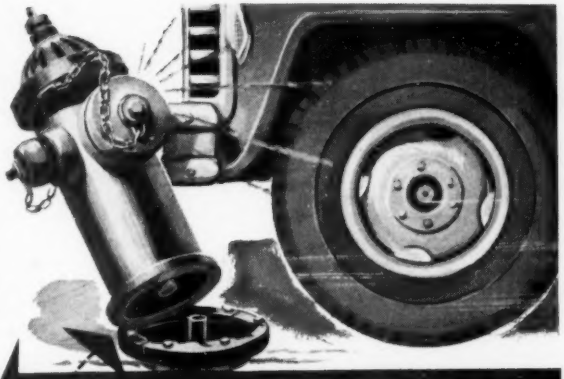

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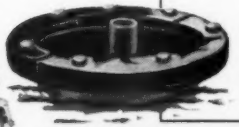

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Coming Meetings

(Continued from page 6)

Oct. 19–21—Chesapeake Section, at Sheraton Park Hotel, Washington, D.C. Secretary, Carl J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Oct. 20–22—New Jersey Section, at Madison Hotel, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 24–27—Rocky Mountain Section, at Broadmoor Hotel, Colorado Springs, Colo. Secretary, Harrison F. Kepner, Vice-Pres., Dana Kepner Co., 550 Alcott, Denver, Colo.

Oct. 25–27—California Section, at Lafayette Hotel, Long Beach. Secretary, F. F. Watters, Hydr. Engr., State Bldg., Civic Center, San Francisco 2.

Oct. 26–28—Ohio Section, at Deshler-Hilton Hotel, Columbus. Secretary, J. Howard Bass, Henry P. Thompson Co., 1720 Section Rd., Cincinnati.

Nov. 9–11—North Carolina Section, at Robert E. Lee Hotel, Winston-Salem. Secretary, T. Z. Osborne, Asst. Director of Public Works, Greensboro.

Nov. 13–16—Florida Section, at Galt Ocean Mile Hotel, Fort Lauderdale. Secretary, John G. Simmons, Plant Supt., Water Dept., West Palm Beach.

OTHER ORGANIZATIONS

Jun. 20–Jul. 1—Course on "Aquatic Biology for Engineers," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Jun. 20–24—Summer general meeting, AIEE, Atlantic City, N.J.

Jun. 26–Jul. 1—ASTM, Chalfonte-Haddon Hall, Atlantic City, N.J.

Aug. 15–19—Course on "Recent Developments in Water Bacteriology," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Aug. 22–27—Seventh Internation Conference on Coastal Engineering, Kurhaus, Scheveningen, The Hague, Netherlands. Write: J. W. Johnson, Engineering Field Station, Bldg. 159, Univ. of California, Richmond 4, Calif.

Aug. 23–25—Symposium on water quality data collection and utilization, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Director, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Aug. 29–31—Symposium on water quality measurement and instrumentation, R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Director, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Sep. 18–22—NEWWA, Queen Elizabeth Hotel, Montreal, Que.

Oct. 2–6—WPCF, Convention Hall, Philadelphia, Pa.

Oct. 10–14—Fall general meeting, AIEE, Chicago, Ill.

Oct. 17–21—48th annual National Safety Congress, Chicago, Ill., with sessions on industrial safety scheduled for Conrad Hilton, Pick-Congress, Sheraton Towers, Morrison, and La Salle hotels. Write: R. L. Forney, Secy., National Safety Council, 425 N. Michigan Ave., Chicago 11, Ill.

Nov. 27–Dec. 2—Annual meeting, ASME, Statler Hilton Hotel, New York, N.Y.

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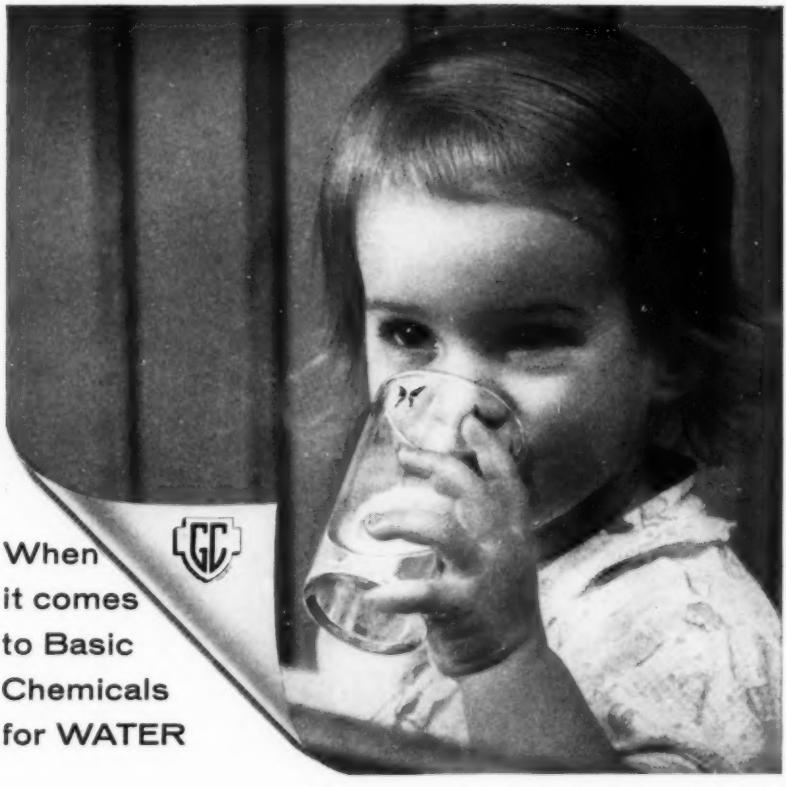


...come to General Chemical!

There are good basic reasons for making General Chemical your source of supply for basic chemicals. Our large-scale production is one. Long experience is another. And there are many more—including consistent high quality and uniformity of product . . . top-notch technical service . . . a coast-to-coast network of plants and distribution points . . . plus efficient follow-through from order to delivery and beyond that to satisfactory performance. That's why—when you need basic chemicals—come to General Chemical for all these products. . . .

COAGULATION
Aluminum Sulfate, Standard
Aluminum Sulfate, Liquid
Ammonium Alum
Potassium (Potash) Alum
Sodium Silicate

FLUORIDATION
Sodium Fluoride
Sodium Silicofluoride
Hydrofluoric Acid

DECHLORINATION
Sodium Sulfite
Sodium Bisulfite, Anhy.
Sodium Thiosulfate

BOILER WATER
Sodium Sulfate, Anhy.
Disodium Phosphate, Anhy.
Trisodium Phosphate
Sodium Silicate
Sulfuric Acid

CORROSION CONTROL
Sodium Silicate
Tetrasodium Pyrophosphate
Sodium Tripolyphosphate

OTHER USES
Aqua Ammonia
Hydrochloric Acid (Muriatic)

Baker & Adamson® Laboratory Reagents and Fine Chemicals

Basic to America's Progress

Allied Chemical

GENERAL CHEMICAL DIVISION
40 Rector Street, New York 6, N. Y.

SOUTHERN HOSPITALITY—JEFFERSON PARISH STYLE

Jefferson Parish, adjacent to New Orleans and divided by the busy Mississippi River, is host to many new plants and homes. To welcome these newcomers, the parish has just added a new 500,000 gallon elevated water tank at Marrero, Louisiana. Designed, fabricated and erected by Graver, it identifies Jefferson Parish as a progressive area, ready and willing to receive new citizens. Graver can help you do precisely the same!

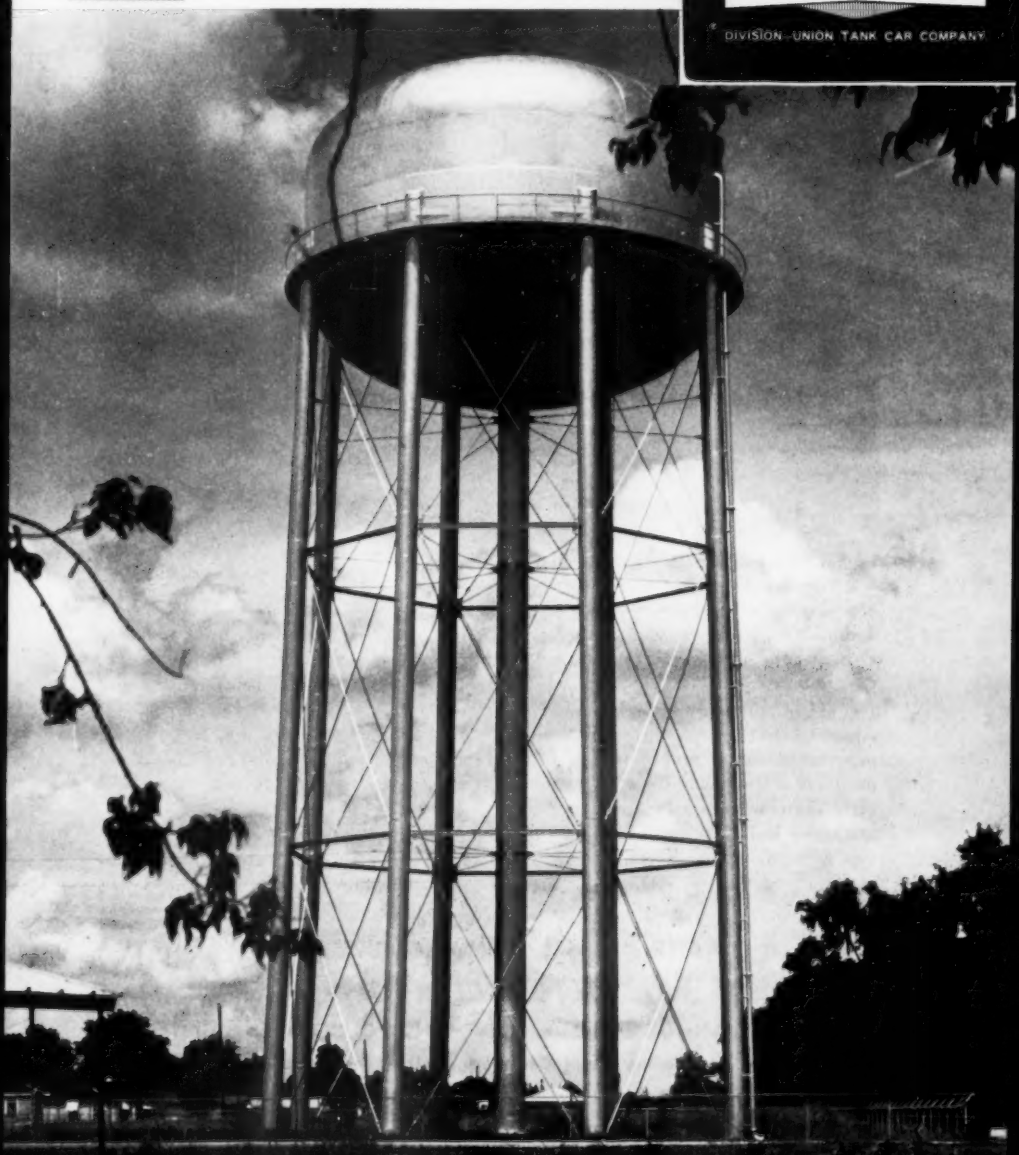
Graver Tank & Mfg. Co.

EAST CHICAGO, INDIANA

PLANTS AND OFFICES ACROSS AMERICA

Graver

DIVISION—UNION TANK CAR COMPANY



34,000 reasons why St. Cloud depends on

Bailey!

...Serving a population of 34,000 Minnesotans requires up to 9,000,000 gallons of water per day. Controlling and recording the operation of St. Cloud's six filtering beds are six Bailey Filter Operating Consoles. This modern water treatment plant went into service in February, 1957.

Engineers: Consoer, Townsend & Associates
Mechanical Contractor: George A. Bass Construction Co.

Keeping pace with the ever-increasing demands for water to supply population growth and industrial expansion, is no easy job.

But more and more cities are proving equal to the task by adopting newer, more economical and more scientific methods of water handling. And to simplify the complete operation, they are installing Bailey Instrument and Control Systems. Because Bailey can furnish *complete* control systems . . . made up of *standardized* components . . . that not only do a better job, but can easily be expanded to meet future needs.

Engineers, water superintendents and city officials themselves will tell you that Bailey telemetering and control systems are outstandingly reliable and economical, attractive, and easy to maintain.

Ask your qualified Bailey Engineer to help you plan your water works expansion program. W-4.5

WATER & WASTE TREATMENT DIVISION

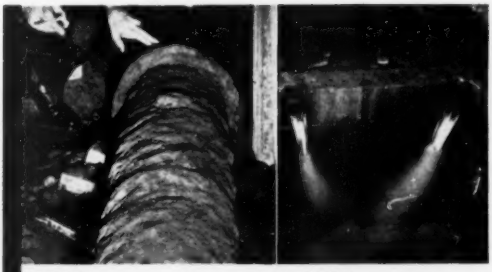
BAILEY METER COMPANY

1024 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada — Bailey Meter Company Limited, Montreal

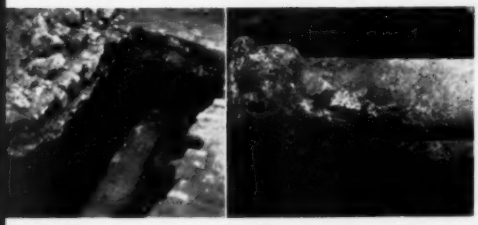
BAILEY METERS

TIME IS THE Only TEST THAT TELLS



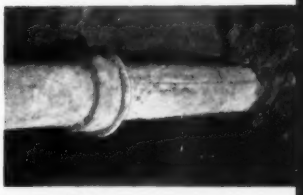
1816 MONTREAL, CANADA *10" Water Main*

1834 READING, PA. *4" Water Main*

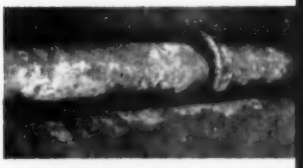


1834 BALTIMORE, MD. *10" Gas Main*

1830 PHILADELPHIA, PA. *6" Water Main*



1831 RICHMOND, VA. *8" Water Main*



1828 LYNCHBURG, VA. *7" Water Main*

Many claims for "long life" and "low maintenance" are being made today by many kinds of johnny-come-lately substitutes for permanent CAST IRON PIPE.

But none of these claims are backed by the *only test* that provides positive proof of the length of time that pipe will give trouble-free service in city water mains.

That test is TIME.

Today 111 Cities Are Still Using Cast Iron Pipe That's a Century Old or More

No other pipe ever made can match this record of long-lived service. Today's modernized Cast Iron Pipe is even more economical and efficient . . . stronger, tougher and more uniform in quality.

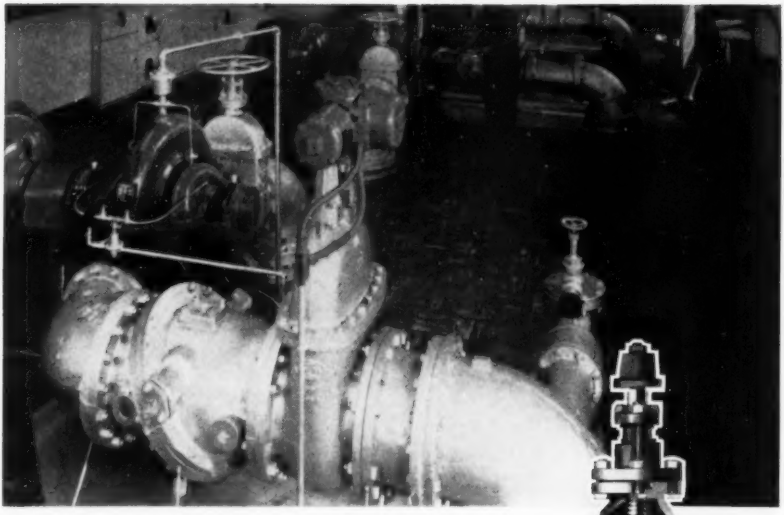
That's why this year, as every year, more miles of underground Cast Iron water mains are in use than all other kinds of pipe combined.

This advertisement is published in the interests of the Cast Iron Pressure Pipe Industry by .....

WOODWARD IRON COMPANY

Since 1882

WOODWARD, ALABAMA



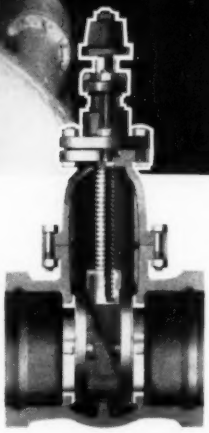
Sustained top performance

. . . a **DARLING** gate valve bonus!

HERE'S a point to bear in mind about the Darling valves installed in this fine new water pumping station at Tonawanda, N. Y. As in so many other applications everywhere, those Darling gate valves are bound to grow old, in years, but they'll *stay young* in performance!

It's the precision manufacture and the Darling fully revolving double disc parallel seat principle that always makes a world of difference! It means prolonged tight closure, avoidance of trouble and low maintenance through the years.

Look into these facts . . . and make Darling gate valves *your* first choice. They are available in types, sizes and with the proper ends for virtually all requirements. Send for Bulletin 5710.



This cutaway shows the Darling principle that assures uniform wear distribution, automatic seating compensation, prolonged tight closure and unusual valve life.

DARLING VALVE & MANUFACTURING CO.

Williamsport 23, Pa.

Manufactured in Canada by The Canada Valve & Hydrant Co., Ltd., Brantford 7, Ont.

DARLING VALVES

Here's the Fast Economical Way

TO TRENCH FOR Water Service Lines!

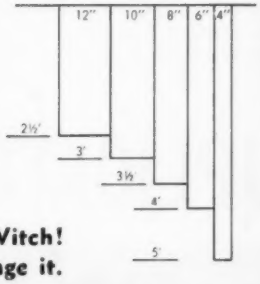
DITCH WITCH TRENCHER

Produces The MOST Trench for the LEAST Money!

USUAL OVERALL COST

2¢ PER LINEAL FOOT

including operation, maintenance, depreciation!



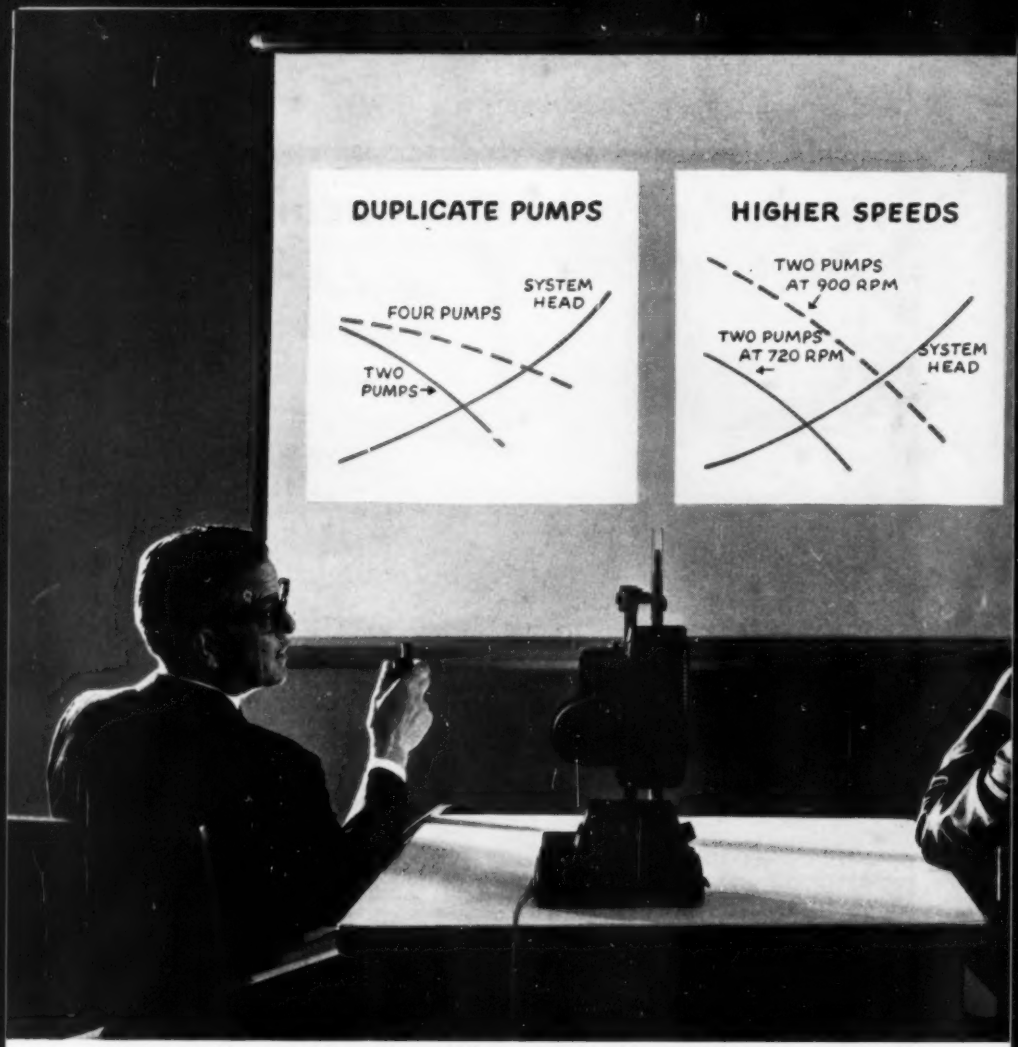
Cut costs on service line trenching with Ditch Witch! The 12 HP Model M-322 illustrated digs at 1½ to 6 FPM—even up to 12 FPM, depending upon soil. Chart at right shows standard trench sizes. Other models offer different ranges.

Local distributors demonstrate Ditch Witch! Call Charles, phone FE 6-4404, to arrange it.

Manufactured by

CHARLES Machine Works, Inc.

649 BIRCH STREET
PERRY, OKLAHOMA



Two ways of taking care of future demands for increased capacity are shown here. The chart on the left indicates the performance of 4 pumps operating in parallel. The chart on the right indicates the same conditions obtained with the use of 2 pumps operating at higher speeds.

DUPLICATE PUMPS OR HIGHER SPEEDS?

A discussion of the economics of multi-speed pumps for water works

WATER WORKS REPORT
from Worthington

Today, most engineers plan for expansion by providing space for duplicate pumps, or pumps that will operate in parallel giving increased capacity as water demand increases.

Another way of taking care of increased capacity is through the use of higher speeds. By providing for multi-speed operation in the future, it may be possible to save thousands of dollars. Spare parts, as well as maintenance costs, can also be reduced.

The charts above show how this can be done. Suppose your water works now uses two 60 hp centrifugal pumps. Sometime in the future you plan to increase capacity by one-third by adding two more pumps which will operate in parallel. The total cost of the four pumps and motors installed would be approximately $26,000.

This same increase in capacity, in some instances, can be accomplished by multi-speed pumping. If you initially made the proper provisions, you could later increase the speed of the two pumps from 720 rpm to 900 rpm. This would give you the necessary capacity increase of 33⅓%. And the total cost would be only $21,000, a saving of $5,000 or approximately 20%.*

It's not necessary to limit your thinking to two-speed operation. Possibly the most economic proposal for your system would be three or four-speed operation. All public water-supply systems are different and pumping equipment is affected by different capacities, suction conditions, and static and friction heads. Therefore, all factors must be known before deciding on the proper approach. This sort of planning, however, combined with the use of multi-speed pumping when appropriate, can save you large amounts of money.

Ask your consulting engineer about the merits of multi-speed pumping. He'll explain to you its many advantages. And for unbiased equipment recommendations, get in touch with Worthington. Worthington makes all types of pumps and drives and a complete line of engines, compressors, and auxiliary equipment.

For a reprint of an engineering discussion of multi-speed pumping for water works, write to Worthington Corp., Section 105-4, Harrison, N. J. In Canada: Worthington (Canada) Ltd., Brantford, Ont.

*Cost figures are estimated and conservative. No cost has been added for additional space required by the extra pumps.

WORTHINGTON

hurry up with the trench! ...here comes time-saving

...American Fastite® Joint Pipe

Time it!... the extra minutes saved in installing AMERICAN Fastite® Joint Pipe for water, sewage and other liquid service soon add up to many dollars saved in installation costs.

A minimum of labor and equipment is required in completing this simple, all-weather, 3-step assembly: (1) Insert gasket; (2) Lubricate plain end; (3) Push pipe together... that's all, and it's bottle-tight!

Why delay? Investigate how you, too, can realize maximum installation economies with fast-laying AMERICAN Fastite® Joint Pipe. Contact your nearest American Cast Iron Pipe Company representative today.

AMERICAN CAST IRON PIPE CO.
BIRMINGHAM ALABAMA

SALES OFFICES
New York City • Dallas
Chicago • Kansas City
Minneapolis • Denver
Cleveland • Pittsburgh
Orlando • Birmingham

What Every

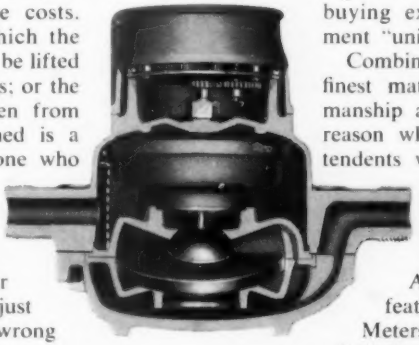
WATER SUPERINTENDENT

Should Know About

AMERICAN METERS

Simplicity

Unequalled simplicity and accessibility of working parts are features of American Meters that reduce maintenance costs. The ease with which the internal gears may be lifted from their bearings; or the disc chamber taken from its seat and opened is a revelation to anyone who has not seen it. And, best of all, you can't put the parts of an American Meter together incorrectly. They just won't fit in the wrong place.



American Meters have full interchangeability of *individual* parts, which permits the low cost rebuilding of worn meters without buying expensive replacement "unit assemblies".

Combine all this with the finest materials and workmanship and you have the reason why water superintendents who know American Meters continue to purchase more, year after year.

All the cost-saving features of American Meters are described in Bulletin 58. We will be glad to mail you a copy on request.

BUFFALO METER COMPANY

INCORPORATED

Subsidiary of American Meter Co., Inc.

2914 Main Street • • Buffalo 14, New York

OMAHA *chose* STEEL PIPE *for* FEEDER MAIN

. . . every length was hydrostatically tested in the shop to AWWA standards!

Maximum length and minimum wall thickness, as only steel pipe provides, enabled the Metropolitan Utilities District of Omaha to install a big pipe line through a quiet residential district with little inconvenience. Only 180 ft. of narrow trench was open at one time to install the coal tar enamel coated 48 in. diameter, ⅜ in. wall thickness steel pipe in. 40 ft. lengths.

Workers of the Metropolitan Utilities District, under the direction of General Superintendent Kenneth Young, are shown lowering a section of pipe into place in the trench just a few feet behind the digger.

STRENGTH
TIGHTNESS
ELASTICITY
ECONOMY
LONG LIFE

. . . these are inherent qualities of fabricated *steel* pipe. Compare *steel* pipe with other types . . . you'll see why "wherever water flows, steel pipes it best." You can always specify *steel* pipe with confidence.

For your copy of the latest steel pipe brochure, write—

STEEL PLATE FABRICATORS ASSOCIATION
105 West Madison Street • Chicago 2, Illinois

STEEL PLATE FABRICATORS ASSOCIATION

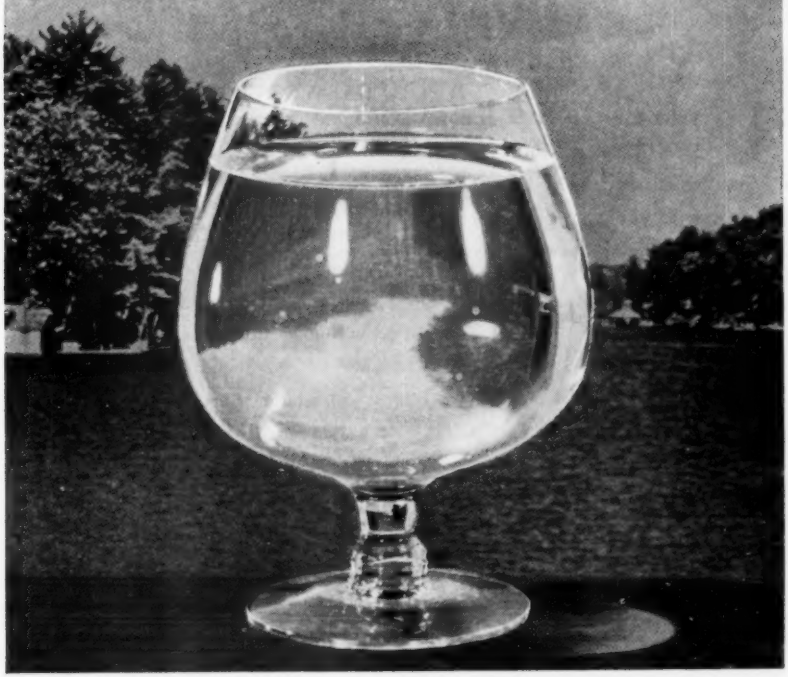
In all phases of water treatment–

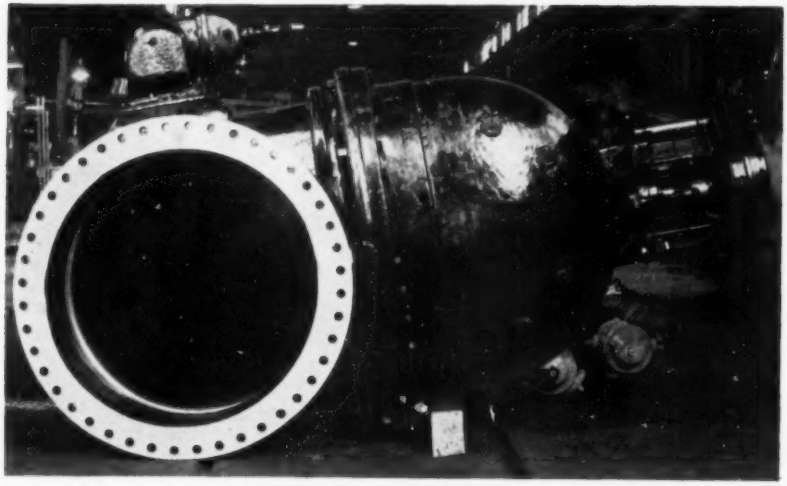
In reservoirs, wells, pipe lines, filtration equipment . . . dry, free-flowing HTH with 70% available chlorine kills germs, algae, odors, and fungi fast. Its high rate of stability keeps HTH at original strength longer, too. Comes in granular or tablet form . . . easy to use and store . . . packed in cans, pails or drums. Write for the name of your nearest HTH distributor.

HTH® is a trademark

Here's **T**o **H**ealth

OLIN MATHIESON CHEMICAL CORPORATION
Chemicals Division • Baltimore 3, Maryland





Whatever your A.W.W.A. Valve requirements . . .

check FIRST with

KENNEDY VALVE

THIS KENNEDY A.W.W.A. Valve, now in service, is a 48" KENNEDY fig. 56IAEM non-rising stem flanged gate valve with enclosed cast steel cut teeth spur gears and 8" by-pass. Railroad tracks in the foreground indicate overall valve size.

Here's another practical demonstration of KENNEDY Valve's ability and experience in providing the right valve for the job, regardless of size.

Since 1877, KENNEDY Valve has been manufacturing quality valves, some of which are still in service. This KENNEDY experience and know-how can help you cut maintenance costs with long, trouble-free service life.

So, whatever your A.W.W.A. Valve requirements, consult KENNEDY *first*. Be sure to get the best!

• *Write for detailed Brochure 561*

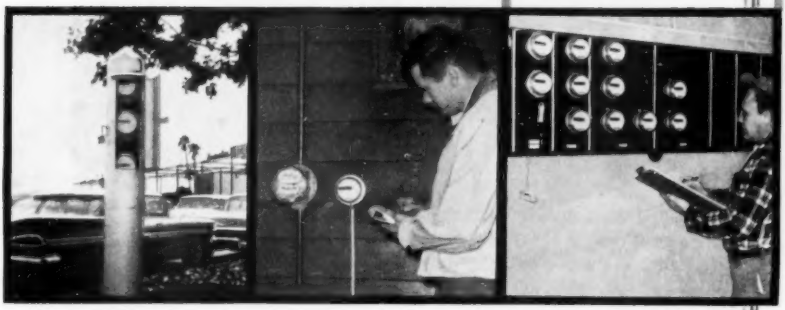
KENNEDY VALVE MFG. CO.

ELMIRA, NEW YORK

• OFFICE AND WAREHOUSES IN PRINCIPAL CITIES

DUCTILE IRON VALVES • CAST IRON VALVES • BRONZE VALVES • INDICATOR POSTS • FIRE HYDRANTS

Badger *Read-o-Matic's** cost-cutting story is big as all outdoors



*Pat. applied for in U.S.A. and foreign countries.

All over the country water departments cut meter-reading costs and increase efficiency with Badger Read-o-Matic outdoor meter-registers.

Read-o-Matics can be installed in convenient "reading stations" which a meterman reads quickly and easily. A safer system too, it eliminates dangers of underground vaults and other inconvenient meter locations.

Install this faster, lower-cost reading system in your water department. Write for literature or call your Badger representative for a demonstration.

Badger Meter Mfg. Co.

4545 W. Brown Deer Rd., Milwaukee 23, Wisconsin

12A-60

ELECTRO RUST-PROOFING 25 YEARS OF SERVICE 1935 1960

This year is your 25th anniversary. It's twenty-five years since you asked for corrosion prevention. It's twenty-five years since Electro Rust-Proofing designed and installed your first cathodic protection system.

ERP has expanded in those years. Today, ERP's worldwide organization protects pipelines, water towers, clarifiers, docks, ships' ballast tanks, and other submerged and buried metals. We've improved our methods . . . pioneered new equipment . . . brought automation to cathodic protection.

We're working now to give you even greater value, even better service for your cathodic protection dollar. To us, this milestone is not a monument. It's a stepping stone towards a corrosion-free future—with ERP.

To those who don't yet know us—we'll be happy to meet you. Just write to Dept. E 54.05.

ERP CATHODIC PROTECTION SINCE 1935

ELECTRO RUST-PROOFING CORP.
A SUBSIDIARY OF WALLACE & TIERNAN INC.
30 MAIN STREET, BELLEVILLE 9, NEW JERSEY
CABLE: ELECTRO, NEWARK, N. J.

SYMBOLIC LOGIC

AEIOU ≠ (AWW = Z)

Take the phrase

"AMERICAN WELL WORKS OR EQUAL—"

Let AWW *stand for American Well Works*

Let Z *stand for all things equal to* AWW

Let the entire set of "vocal vowels" stand for what's not equal to AWW

Now, AWW *has the following attributes:*

- Experience rating of 92 years.
- Its sole business is engineering, design and manufacturing of equipment for sewage treatment, water purification, mixing and pumping. It has no outside activities.
- It owns extensive plant, equipment and manufacturing facilities all on one site to assure complete quality control.
- All of its products are unconditionally guaranteed as to function and performance.
- Its products are reasonably priced to enable owners and engineers to stay within estimates.
- It offers latest proved methods and designs.
- It has the highest available mercantile credit rating.
- It has the largest list of satisfied users in the United States.

THE PROBLEM:

Ignoring the entire set of "vocal vowels" (which are admittedly not equal to AWW*) solve for* Z *(what's equal to* AWW*)*

HINT FROM AWW *ENGINEERING DEPARTMENT:*

Even if Z *could easily be determined,*

Take AWW *for assured advantages*

AMERICAN WELL WORKS AURORA, ILLINOIS

Costs go down

as fast as the pipe!

Lancaster, Pennsylvania: Ten miles of 42-inch ID steel main are an important addition to the local water supply system. The 100 per cent Dresser-Coupled line was laid by Frank Kukurin & Sons and Alconn Utilities.

AND DRESSER-COUPLED steel pipe goes in fast! Steel pipe in lengths up to 50-feet needs fewer connections, and Dresser® Couplings make those connections fast . . . two man-minutes per bolt. Steel pipe is lighter . . . saves freight costs and provides easier handling at the job-site. When you use Dresser-Couplings to join steel pipe, you eliminate the need for expensive, specialized joining equipment. The only tool you need is a simple hand wrench. For *least initial cost* and *lowest maintenance* on your next water line, specify Dresser-Coupled steel pipe.

Two man-minutes per bolt for permanent, leak-proof joints!

Bradford, Pennsylvania
Chicago
Houston
New York
Philadelphia
S. San Francisco
Toronto & Calgary

DRESSER
MANUFACTURING DIVISION

ONE OF THE DRESSER INDUSTRIES

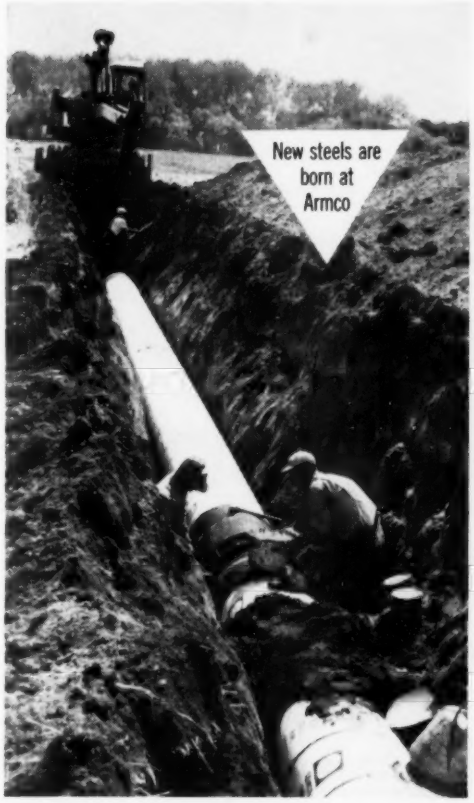
Aberdeen saves $104,000 with Armco water pipe

Steel

When Aberdeen, South Dakota, needed an additional water transmission line to run from the water works to a storage tank inside the city, they used Armco Steel Pipe for the job. Armco's bid to supply 32,290 lineal feet of 24" steel water pipe was $104,068.65 under that of the nearest competitive bidder.

Aberdeen's Mayor, J. Clifton Hurlbert, had this to say about the installation: "This pipe was installed without experiencing any difficulty whatsoever, and all tests proved satisfactory."

This example is only one of many in which Armco Steel Pipe has saved customers time and money. Get complete information on how this pipe can serve *you*. Write to Armco Drainage & Metal Products, Inc., 6840 Curtis Street, Middletown, Ohio.

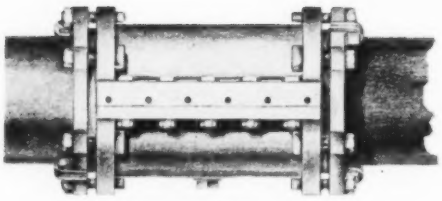


ARMCO DRAINAGE & METAL PRODUCTS

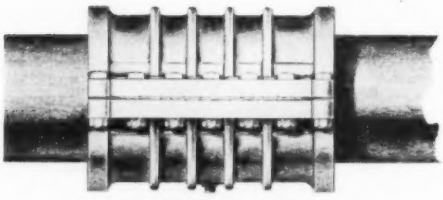
ARMCO

Subsidiary of ARMCO STEEL CORPORATION

OTHER SUBSIDIARIES AND DIVISIONS: Armco Division • Sheffield Division
The National Supply Company • The Armco International Corporation
Union Wire Rope Corporation



Mechanical Joint Repair Sleeve



Bell (Hub) End Repair Sleeve

INSTALL A SMITH SLEEVE

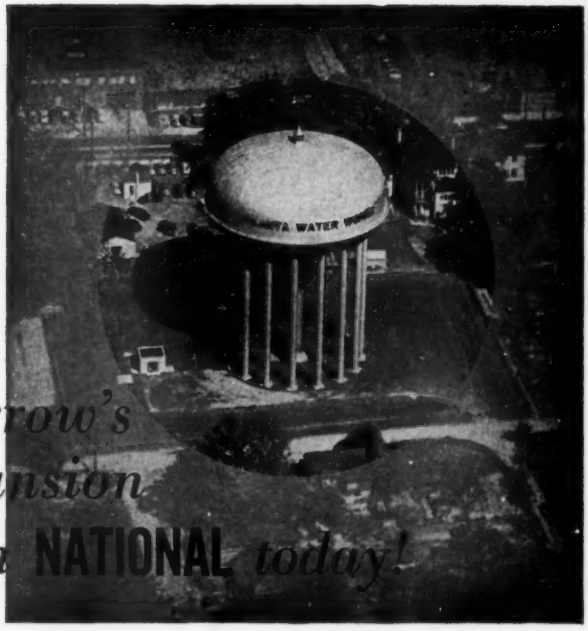
Smith Repair Sleeves are the answer to permanently repairing and quickly returning broken and cracked piping to service. Two types of Smith Repair Sleeves are available for installation on standard classes of cast iron pipe. Smith Mechanical Joint Repair Sleeves are produced in sizes 4″ thru 12″; Smith Bell (Hub) End in sizes 4″ thru 48″. Unskilled labor can speedily install Smith Mechanical Joint Repair Sleeves even in wet excavations. Bell End Repair Sleeves are most frequently installed with caulked lead joints. Smith Repair Sleeves reenforce the broken — cracked pipe and their service life equals the life of the pipe.

63

FIRE HYDRANTS · VALVES · SINCE 1896

THE A.P. SMITH MFG. CO.

EAST ORANGE, NEW JERSEY



For tomorrow's expansion call in **NATIONAL** *today!*

Like Atlanta, Ga., *you* too can meet tomorrow's increased water demands with *clean water mains.* When the coefficient of sections of Atlanta's 45 year old main dropped to a low of 44, Waterworks General Manager, Paul Weir ordered National cleaning. Results were outstanding. Water pressure and capacity doubled, giving better fire protection and higher water pressure to outlying sections.

Do as other leading cities have done—let *National* cleaning provide for tomorrow's expansion without capital expenditure today! We can prove that National cleaning is an investment—not an expense.

Write us today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn., 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Marafi., Lima, Peru

Concrete Pressure Pipe...

MEANS MORE WATER FOR MORE YEARS AT LESS COST

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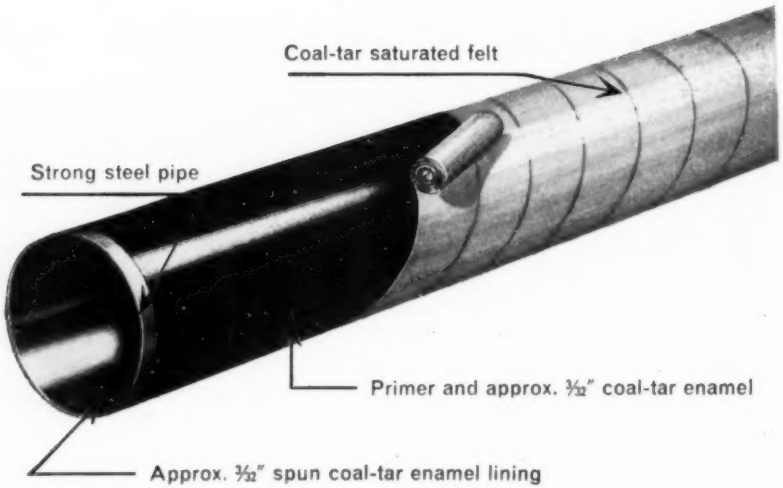

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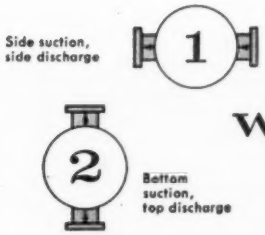

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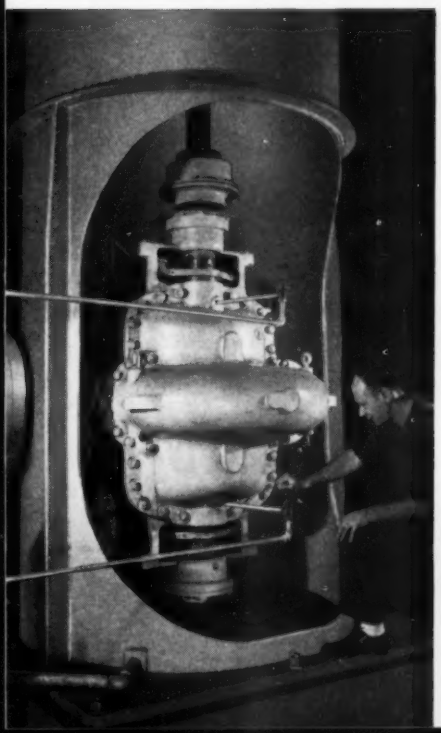

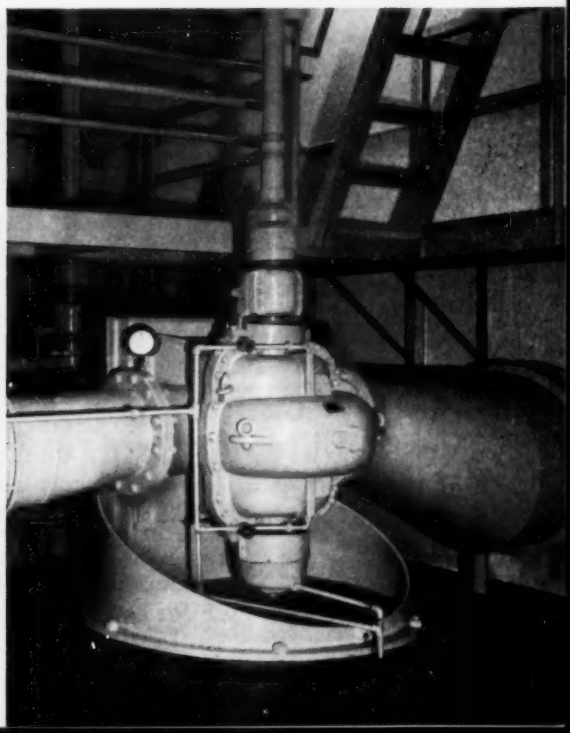

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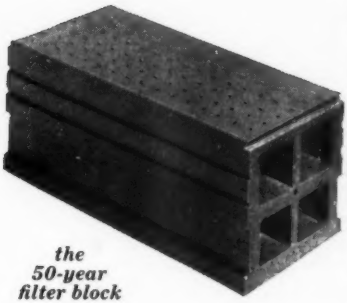

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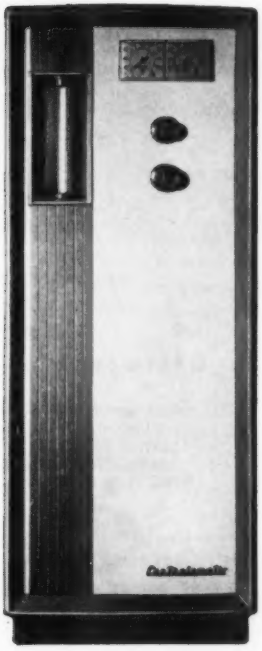

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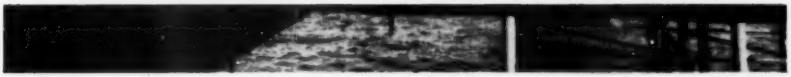

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Journal

AMERICAN WATER WORKS ASSOCIATION

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Proposed Toxicity Screening Procedure for Use in Protecting Drinking-Water Quality

M. B. Ettinger

A contribution to the Journal by M. B. Ettinger, Chief, Chemistry & Physics, Water Supply & Water Pollution Research, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio. The procedure described here is under consideration by the USPHS Advisory Committee on Revision of the Drinking Water Standards, which has AWWA representation. Suggestions or comments concerning this proposal or other related matters should be directed to the author or to the AWWA representative, Oscar Gullans, 3300 E. Cheltenham Place, Chicago, Ill.

MORE than 500,000 organic chemicals are known and have been synthesized and described. A few dozen of them are accepted by the Food and Drug Administration as being safe for addition to food and beverages. Tolerance levels, varying according to the food, have been established for a few pesticides.[1] The zero tolerance is relatively common, and is directed by law in some instances.

There is a vast area of ignorance concerning the toxicology and pharmacology of both synthetic and naturally occurring organic materials, and new materials are being made much faster than the toxicology of known materials is being studied.

Most surface waters receive a large, variable, and anonymous load of organic chemicals. Only a minute fraction of the materials dumped or washed into surface waters could hope to qualify with the Food and Drug Administration as acceptable for addition to food and beverages, and the water utility operator can usually be confident that his surface water is subject to pollution by chemical pesticides which have been assigned low tolerances or even a zero tolerance by the Food and Drug Administration. The responsible water producer must feel some concern about how wholesome the water he furnishes the consumer may be.

The problem of keeping toxic material out of drinking water parallels that of keeping pathogenic material out. It is difficult to detail all pathogens which may conceivably be waterborne, and it

is absurd to ask water utilities to check treated water for each specific organism or virus to insure that it is not present. The same is true of toxic materials. Fortunately, the relatively simple observation of coliform organisms has served as a theoretically imperfect but practically workable measure for protecting water from pathogens. Assuming that some similar blanket safeguard against exposure to toxicants is desirable, how can it be provided?

Only a few micrograms per liter is the minimum concentration of some organic materials that can produce toxic reactions in man. There is, however, little likelihood that material of such extreme physiological effect is introduced into water supplies by the ordinary industrial activities of man.

Toxicity Index Requirements

A nonspecific analytic criterion to serve as a toxicity warning should:

1. Be suitable for execution by the water utility at a reasonable cost
2. Afford the maximum possible protection against the intrusion of unknown or undetected toxic materials
3. Be a criterion that all or almost all safe and acceptable water supplies can meet
4. Be based upon examination of an integrated or composite sample, as the problem is primarily one of chronic toxicity rather than acute toxicity
5. Have further value in promoting good water utility operation.

No test or criterion that has yet been devised can satisfy all these requirements. This is not, however, a good reason for failing to adopt the closest possible approach to the ideal criterion. Such a practical criterion obviously should relate to finished drinking water and be an index principally to the organic toxicants of greatest public health concern. As a standard it should be a value measurable by some well defined technique and reducible to a simple number.

Proposed Criterion

The carbon filter technique has been described previously in some detail.[2, 3] The criterion proposed relates to the material concentrated by activated carbon in the filter from about 5,000 gal of water, and subsequently eluted from the dried carbon by repeated extraction with chloroform in a very large Soxhlet-type extractor.

In the carbon filter technique, as it is now used, a second series of extractions is usually made with ethyl alcohol to recover a further extract. The total carbon filter extract provides a variable and incomplete recovery of the organic materials present. It is no more than a substantial fraction of the total organic material present in a sample of surface water.

Limitations of Method

The mechanics of the carbon filter process for sampling the water causes a first series of restrictions. If a substance cannot be adsorbed from the water sampled by the carbon filter, then it is not available for extraction by chloroform. Chloroform extraction obviously recovers only material soluble in chloroform and extractable by the solvent from the carbon. Knowledge of precisely which compounds can be collected by the procedure is limited.

Some materials, such as simple hydrocarbons and chlorinated insecticides, can be recovered almost quantitatively. Other compounds, such as the alkyl benzene sulfonates, may be quantitatively collected but will not be removed

by the chloroform, although they can be removed almost quantitatively by other solvents. About 60–70 per cent of some substances, such as simple phenols, are recovered by chloroform extraction even though they are adsorbed quantitatively from the water originally put through the carbon filter. Materials such as sugars, polysaccharides, proteins, and tannins, have not been observed in chloroform extracts. These materials are either insoluble in chloroform or not extractable by chloroform from carbon, or the carbon column is unable to remove them from water.

It might be thought that the carbon filter would readily develop into an efficient device for biological attrition of the material dissolved in the water submitted to it. This apparently is not the case, and with reasonable precautions in handling, losses as a result of biological destruction are believed to be small or negligible. The quantity of extract recovered is affected by the pH of the water submitted to the carbon. Variations in the pH of satisfactory waters are believed to have little effect, as most of the extract is ordinarily neutral or only very weakly acidic or basic.

Characteristics of Samples

Carbon filter sampling of waters remote from concentrated industrial areas or heavily populated regions invariably yields a small chloroform-soluble extract, usually less than 50 ppb. Large amounts of chloroform-soluble extract appear in industrial effluents, especially if they have not been given much treatment. Values as high as 3,000 ppb have been observed in a raw municipal supply during a period of exceptionally heavy industrial pollution.[4]

Figure 1 shows the distribution of the data on concentrations of chloroform extractables yielded during the first 2 years of the USPHS program to collect basic data on water quality.[5] Principal streams all over the United States were sampled at approximately 50 points. Analytical data were pooled to make up the "total" curve presented. The median concentration of chloroform-soluble extract recovered was 47 ppb and only 19 samples of 750 showed values in excess of 200 ppb. In addition to the distribution of the chloroform-soluble carbon filter extracts in the total data, curves are presented showing the data on the Mississippi, Missouri, and Ohio rivers.

The stations of the national data collection network active during the period reported represent a reasonable cross section of the surface water available in the United States.[6] A detailed breakdown of the 19 samples in which the concentration of chloroform extractables exceeded 200 ppb is instructive. Of the 19 samples, only 9 were taken from a city water inlet; 10 were secured at points where the city uses well water, or where the municipal water inlet has been placed in another location for good reasons. For instance, at Lowell, Mass., the samples were taken from a site on the Merrimack River abandoned when the city changed to a well supply; at Poughkeepsie, N.Y., samples were taken below the town from an industrial water inlet which is relatively close to the river bank.

Experience has shown that there is a rough correlation between taste and odor problems and the amount of chloroform-soluble material present. The 200-ppb value cited above has never been exceeded in treated water

where the population served was satisfied with the water delivered. According to data covering a period of 4 years,[3] the 200-ppb concentration was exceeded for a sustained period at Cincinnati for only a few months in 1953, and this period was coincident with particularly low flow in the river and sustained consumer distress with the water supply. This concentration is also reported to have been exceeded a number of times at Nitro, W.Va.[4]

In studies of the boundary waters in the general area around Detroit and Windsor, Ont., a number of samples have been found in which the concentration sometimes exceeded 200 ppb in both raw and finished water. Specifically, the cities involved were Wyandotte and Mt. Clemens, Mich.[7]

Water containing less than 200 ppb chloroform extractables is not necessarily of good taste and odor quality, and samples that are relatively low in chloroform extractables can sometimes show surprisingly high odor and taste. It would be easy to suggest compositions of water pollutants which would have no odor and would nevertheless greatly exceed the 200 ppb value. In actual

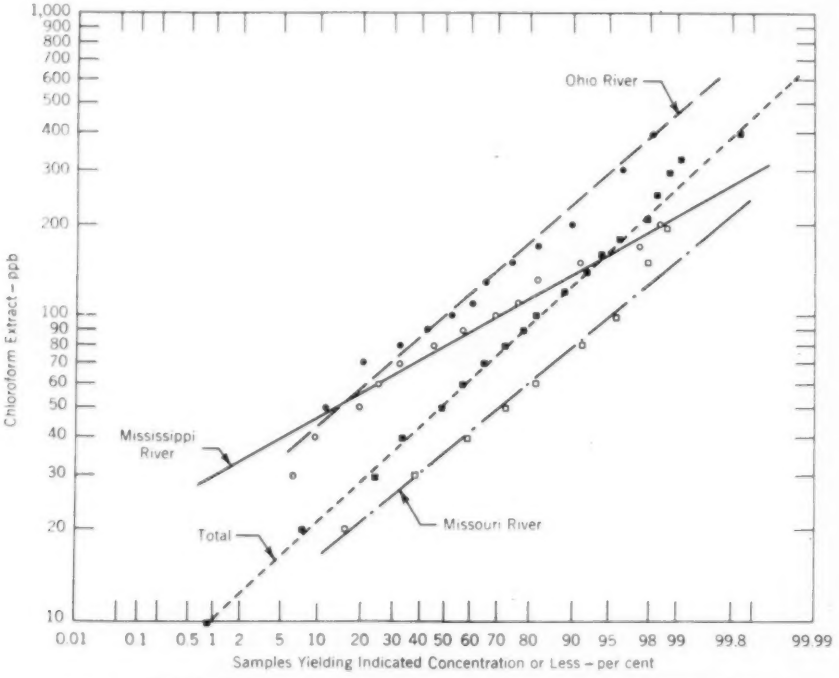

Fig. 1. Distribution of Chloroform Extractables in Major United States Streams, 1957–59

Shown are data on three major streams as well as a "total" curve for carbon filter data from approximately 50 points on principal streams all over the United States.

practice, however, this condition seems to be encountered infrequently, and it is usually followed or preceded by water of an inferior taste and odor quality.

Further Investigations

At the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, chloroform-soluble carbon filter extract has been subjected to further analysis and separation. This work has shown the presence of toxic materials in various waters. Materials recovered include chlorinated insecticides, nitriles, a substituted nitrobenzene, aromatic ethers, and the like. These materials have yet to be found in dangerous concentrations, but all those that have been found so far have been recovered with the chloroform extract. This does not mean that the chloroform-soluble carbon filter extract provides a complete sample of toxicants in water; the finding of toxic materials in the chloroform-soluble carbon filter extract may be the natural result of concentration of efforts on examination of this material. The technique does, however, appear to be valuable for collecting material of industrial origin likely to have toxic properties, and it has the additional advantage of giving a clear and objective indication of whether or not a water supply has been unreasonably burdened with the wastes from industry, humanity, or agricultural practice.

Adequacy of Proposed Technique

The proposed technique is quite suitable for execution by water utility personnel at a reasonable cost, or it can be easily handled by an outside laboratory with only the sampling done by the water utility. The procedure has been used by personnel in both large and small water utilities. In the Taft Center operations of the National Water Quality Network it is routinely executed on shipped carbon filters by subprofessional personnel. The cost is relatively small. Most water utilities should be able to do it for approximately $15 in labor and materials.

Although application of the carbon filter technique has already resulted in the detection of a number of toxic materials in water, there are toxic materials that the proposed test cannot recover. For example, it affords little protection against some of the commercial poisons which are sometimes used in large agricultural fumigation or insect control operations. The test is, however, likely to be at least a good indicator of large amounts of potentially toxic materials released as the result of industrial operations, and it is possible that it will actually collect toxic materials. The proposed measurement could give a substantial amount of protection if used as a standard, and it would afford more protection than could be obtained from any other technically simple and administratively feasible test devised thus far.

Any water supply that would be unable to meet the proposed criterion would almost certainly be unacceptable to the consuming public, for it would have acute taste and odor periodically or continuously. Although it might be sufficient to maintain direct examination of waters for taste and odor, the criterion proposed here is nonsubjective. It does not depend on the judgment of one man or on other variables, such as proximity to heavy industrial operations which make it difficult to carry out reasonable taste and odor examinations because of the high background odor. It is the author's opinion that no high-quality water is likely to be in violation of the proposed crite-

rion for more than very short periods, if at all.

The carbon filter procedure represents a sample that is integrated over a period of approximately 2 weeks, and is therefore likely to reflect the average condition of the water put into the mains over the same period. The concern over the possible dangers of toxicants in public water supplies is largely related to chronic exposure. This means that average conditions are what should be observed rather than short-time exposures to materials that are temporarily present in insignificant amounts.

It is clear that the proposed test could be a valuable adjunct to water utility records. In time it could become a measure of long-time trends of finished-water quality and it would give an indication of the effectiveness of such procedures as carbon treatment.

Results of the chloroform-soluble carbon filter extract determination are likely to be available about 3 weeks after the beginning of the 2-week sampling period. It will report on an integrated average condition during the sampling period. Clearly, the determination relates more to long, sustained organic intrusions than to brief intervals when the water system is under stress.

The criterion serves as an integrated survey of chemical pollution of the watershed and of water system performance in coping with chemical pollutants. Measures that should be considered when chloroform-soluble carbon filter extract is high include improvement of the quality of raw water by a vigorous program of watershed pollution abatement, consideration of alternative sources of water, or development and adoption of treatment procedures designed to remove organic contaminants.

Recommended Limit

A recommended limit for chloroform-soluble carbon filter extract is being considered for incorporation into the next revision of the USPHS Drinking Water Standards. A recommended limit differs from a mandatory limit in that water exceeding a recommended limit may be certified by the USPHS for use on interstate carriers when a more desirable water supply is not available.

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Proposed Method for Examination of Water for Free-Living Nematodes

Shih L. Chang

A contribution to the Journal by Shih L. Chang, Medical Director, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

BECAUSE of current interest in the subject, it has appeared desirable to develop a method of examining sizable quantities of water for free-living nematodes, including collection of water samples, concentration of samples, direct microscopic examination of concentrates, and general identification of nematodes. Such a method is presented below.

Laboratory Apparatus

1. *Sample bottles,* 1 gal, glass or plastic, with metal or plastic screw caps, thoroughly washed and rinsed three times with distilled water.

2. *Capillary pipets,* Pasteur type, 9 in. long, with rubber bulbs of 2-ml capacity.

3. *Filtration unit,* of any filter holder assembly type used in bacteriologic examination.[1] The funnel should be of at least 650-ml capacity and the filter flask of at least 2-liter capacity.

4. *Filter membranes,* of Millipore * SS (SS 047 MM) type or equivalent.

5. *Microscope,* binocular type with 10× eye piece, 4×, 10×, and 43× objectives, and mechanical stage.

Collection of Water Samples

Samples are collected in the same manner as samples for bacteriologic examination,[1] except that a dechlorinating agent is not needed. Samples of 0.5–1 gal are collected from raw water and 1-gal samples from tap water. Refrigeration is not essential, and samples may be transported without it unless examination is to be delayed for more than 5 days.

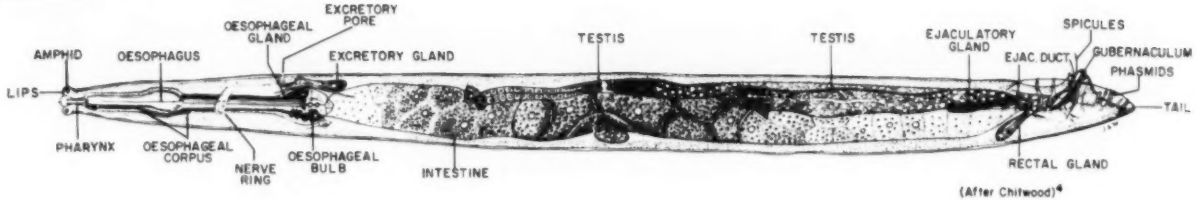
Concentration of Samples

A 1-gal sample of tap water can usually be filtered through a single membrane within 15 min, unless the water is turbid. At least 1 gal of sample should be used in a single examination. Immediately after the last of the water has disappeared through the membrane, the suction line should be disconnected and the membrane should be placed on the wall of a clean 50–100-ml beaker and flushed repeatedly with approximately 2 ml of sterile distilled water. A capillary pipet with a rubber bulb should be used for flushing. The concentrate should then be pipeted into a clean Sedgwick-Rafter counting cell, after which it is ready for examination.

In concentration of raw-water samples having visible turbidity, two to four membranes may be required per sample, with filtration through each membrane being limited to not more than 20 min. Samples ranging from 500 ml to 2 liters may be filtered, depending on whether turbidity is high or low. After filtration the membranes are placed on the walls of separate

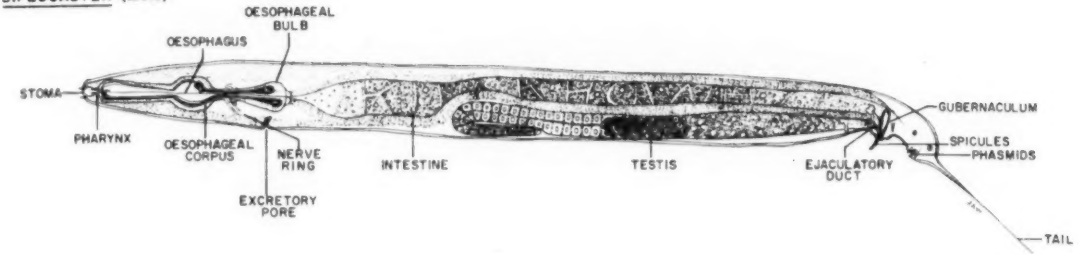
* A product of Millipore Filter Corp., Watertown, Mass.

RHABIDITIS (Male)

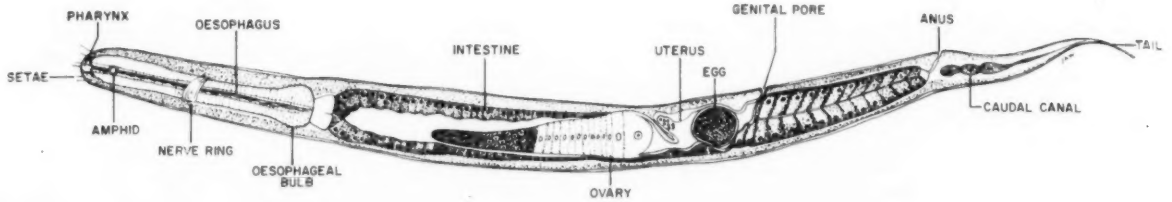


(After Chitwood)[4]

DIPLOGASTER (Male)



MONHYSTERA (Female)



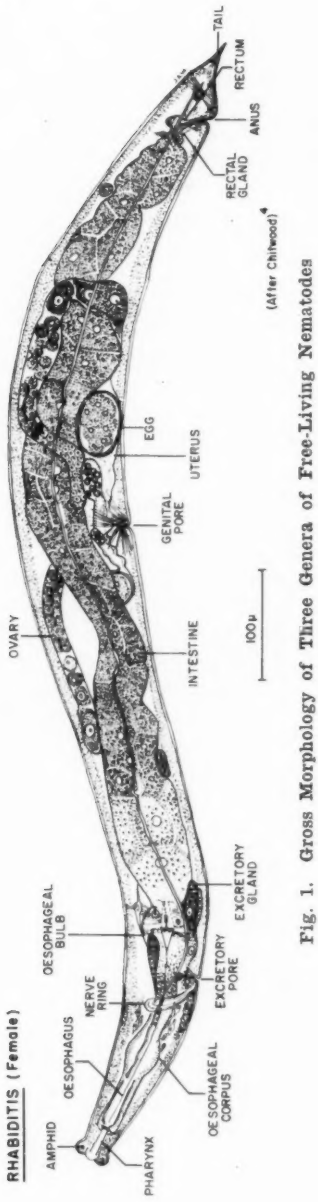


Fig. 1. Gross Morphology of Three Genera of Free-Living Nematodes

beakers and washed as described above. To prevent particulate matter from obscuring the nematodes, the washing from each filter should be examined in a separate counting chamber.

Direct Microscopic Examination

Each counting chamber containing the filter concentrate should be first examined under a 4× objective. Unless the concentrate contains more than 100 nematodes, the whole cell area should be surveyed to determine the number, developmental stage, and motility of nematodes present. When an object having an outline resembling that of a nematode is observed, it should be re-examined under a 10× objective for anatomical structures, unless the object exhibits typical nematode movement, which is sufficient for identifying the object as a nematode. When the concentrate contains more than 100 nematodes, the density can be estimated by counting the number of individuals in representative microscopic fields and multiplying the average number per field by the number of fields in the cell area. The nematode density may be expressed as the number of organisms per gallon, with or without differentiation as to adult or larval stages or as to viability.

General Identification

Whereas actively motile nematodes can be readily recognized by anyone who has some general concept of microscopic animals, nonmotile or sluggishly motile nematodes may be confused with root fibers, plant filaments of various types, elongated ciliates such as *Homalozoon vermiculare*, or segments of appendages of small crustacea. To facilitate a general identification of nematodes, the gross morphology of three of the free-living nematodes that are

frequently found in water supplies is shown in Fig. 1. This drawing provides not only the general anatomic detail necessary for recognition of nematodes, but also most of the essential structures for guidance to those who want to use the "Key to Genera" in chapter 15 of *Ward & Whipple's Fresh-Water Biology*.[2]

Under normal conditions, practically all nematodes seen in samples of finished water are in various larval stages and range from 100 to 500 μ in length and from 10 to 40 μ in width. Except in the fourth (last) stage, the larvae have no sex organs but show other structural characteristics.

If identification of genera is desired, the filter washings are centrifuged at 500 rpm for a few minutes. The supernate is discarded, except for a few drops, and the sediment is resuspended in the remaining water. A drop of the final suspension is examined under both 10× and 43× objectives to determine the anatomic characteristics of the nematodes without staining, and, for supplementary study of structures, the remainder is fixed in a 5 per cent formalin solution or other fixing fluid and stained according to instructions given in *Ward & Whipple's Fresh-Water Biology*,[2] Goodey's *Soil and Freshwater Nematodes*,[3] or other books on nematology.

Acknowledgment

The author is grateful to Paul W. Kabler, chief of microbiology at the Robert A. Taft Sanitary Engineering Center, for reading the manuscript and making helpful suggestions, and to Judith Walters, also of the Taft Center, for making the drawing of nematodes.

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Establishment and Use of Work Standards in Utility Maintenance and Construction

Charles B. Adelmann

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Charles B. Adelmann, Mgr., Operations & Maintenance Div., East Bay Munic. Utility Dist., Oakland, Calif.

IN the field of expenditure control and in the evaluation of supervisory effectiveness, much has been accomplished through the use of accounting reports. Budgets, budgetary controls, and cost accounting systems have furnished top management with a considerable amount of useful information for the overall control of an operation. Unfortunately, the figures furnished by budgets and systems all too frequently are either comparisons with past performance or estimates of expenditures that also are based on historical data. No attempt is made by the cost accountant to determine whether or not the unit cost could be reduced. This usually is left to the unit supervisor, who may or may not be motivated to study his methods in an effort to operate more effectively. If the supervisor himself is interested in the effectiveness of his workers, he usually assesses their efficiency on the basis of his long experience. This method is sometimes unjust, inexact, and weighted heavily by interpersonal relationships.

The problem is to establish a more scientific basis for the measurement of supervision. Of the several ways in which the performance of crews engaged in the construction and maintenance of water systems may be evaluated, probably the simplest way is to determine a total cost for these functions for a given period. Cost information required by the accounting department seldom is detailed enough to provide the supervisor with a measurement of his effectiveness. A simple account of the amount of pipe laid, the number of leaks repaired, or the number of services installed is not adequate because of the wide variance of conditions encountered. Detailed cost reporting that may work well in construction is difficult and expensive to apply to maintenance activities. After experiments were made with various systems, it was found that an objective evaluation is impossible with any of these methods. It is too easy to claim that poor production is the result of extenuating circumstances. It is also easy for supervisors to go along with this explanation. Too much tolerance for poor performance and no fair means of evaluating supervision exist.

The management of the East Bay Municipal Utility District (EBMUD) in Oakland, Calif., was satisfied with the efficiency of its construction and maintenance organization. Any successful manager, however, is never completely satisfied that he has reached the ultimate level of performance. He is not content with just a good organization; it must be outstanding. Ac-

cordingly, management was continuously seeking the means to build an organization that would be recognized as the best in its field. A particular matter of concern was an apparent complacency at the lower levels of supervision. The question was how supervision could be made so keen that even a minor inefficiency would be treated as a matter of importance.

During the study of this problem, EBMUD became aware that other industries were succeeding in setting standards for maintenance work by using long-accepted measurement techniques. In certain applications, the problems of industry paralleled those of EBMUD, and their solutions gave promise of achieving the results desired without costs that would cancel any benefits gained. In order to assure itself further of this, EBMUD employed a management consultant to work with an already established scheduling unit in conducting a pilot study of operations. The results of this study indicated that substantial reductions in operating costs could be accomplished through work measurement and the use of standards. All operations, including maintenance and shop activities, were included in the study.

Work Measurement

Work measurement is the determination of the number of man-hours required to perform defined work units. This measurement results in the establishment of a standard for the work unit, which is established in various ways. One of these is the time-study method,[1] in which continuous stopwatch observations are conducted. This method of establishing a standard is quite accurate, but it has the disadvantage of creating resentment in those who are being measured and is also one of the most expensive means of measurement. Standards may also be established by synthetic means,[2] with the use of standards already established for certain motions. The work unit is divided into these motions, and the accumulated synthetic motion times become the standard for the unit. This method is considered to be inapplicable to underground utility maintenance.

In order to make the measurement of maintenance activities feasible from a cost standpoint, the technique of work sampling is employed,[3] in which a number of observations are made at random, and standards are established through proved statistical methods. This particular means of measurement is most important, because it allows the economical establishment of work standards on almost any kind of work performed.

For a simple example of the way in which work measurement is used, consideration may be given to a standard meter repair job wherein the meter repairman finds it necessary to change the meter. The job is classified into three main divisions: (1) make ready, (2) work, and (3) put away. These are further broken down by task:

1. Make ready
   - *a.* Check house number.
   - *b.* Open meter box and check meter number.
   - *c.* Obtain tools and materials from truck when necessary.
   - *d.* Notify consumer.
   - *e.* Close curb cock.
2. Work
   - *a.* Dig out meter.
   - *b.* Remove meter.
   - *c.* Clean old washers from ends of couplings.

d. Set new meter.
e. Bleed house line.
f. Inspect for leaks.

3. Put away
   a. Clean up job site.
   b. Return tools to truck.
   c. Read meter and complete paper work.
   d. Close meter box.

For each task a standard is established. Individual standards are combined so that a standard is obtained for each of the three main divisions. The meter repairman engaged in the work reports the work accomplished and the actual time it took to perform the work. The actual time is then compared with the standard, to obtain a percentage that is a measurement of effectiveness. If, instead, the work involved the replacement of the dial assembly, it would pertain to the "work" category, and a standard would be set for it. The point to be emphasized is that standards can be established at a reasonable cost regardless of the variables encountered. Standards have been set for leak repair, service installation, meter reading, and all the numerous tasks encountered in utility maintenance.

Work Measurement System

At the time the study was begun, there were approximately 450 people employed directly in the performance of maintenance and construction activities. Of these, 330 were employed in maintenance or construction of distribution system piping; the remaining 120 were employed in shops, structures maintenance, and automobile maintenance. Because of its size, the construction and maintenance activity was selected as a starting point.

The system developed is simple and not difficult to use. Crews were classified by function into four groups: the main pipe installation crews, maintenance and service crews, field meter repair crews, and paving crews. Reporting forms were developed for each of these groups so that a minimum of effort would be required to complete them. These forms list all measured elements and provide space for noting unusual conditions and for reporting delays and "indirect labor" (Fig. 1 and 2). Delays are allowed for rain, breakdowns, and other conditions beyond the foreman's control. Indirect labor includes such items as training and safety meetings. All hours reported as delay or spent on indirect labor are counted as earned hours at 100 per cent effectiveness.

A new organization was necessary. Fortunately, a scheduling supervisor who was a qualified industrial engineer was already employed, and the responsibility for developing the program was assigned to him. Five work analysts were required. Ideally, they should have been selected from the working force, as much of the training time could have been eliminated. Because of the civil service system, however, the analysts did not come from within the organization, as desired, but five competent people were selected for the assignment.

The next two phases of the program were carried on concurrently and occupied a period of about 6 months. First, the analysts were thoroughly trained in the concepts of work measurement and the establishment of standards. The necessary forms for use of the analysts and supervisors were developed. After a certain amount of training had been given the analysts, it was necessary to divide all jobs into work units to be measured and to establish hundreds

of standards by work sampling, time study, and estimation.

At the same time, a concerted effort was made to indoctrinate all levels of supervision and prepare them for the program. The basic reaction among the supervisors to the program—a reaction that must be recognized and compensated for—results from the threat to job security and prestige when such a program is begun. This threat, for the working foreman and supervisor, is an adventure into the unknown; by providing them with an understanding of what is to be achieved, their natural resistance is overcome. Therefore, extreme care was exercised to recognize these fears and to approach the program in such a way that a minimum of reaction would be encountered. In addition, management made a commitment that forces would be reduced only through normal attrition rather than by layoffs. The importance of selling the program to the supervisors cannot be minimized, because without their support a program such as this would probably fail.

At the end of the 6-month period, the first report was published on the effectiveness of the working organization. Under the system of EBMUD,

DAILY CREW REPORT

Date | Code | EH | Job No.

Foreman

Location

ELEMENTS	Amt.	Std.
PAVING BROKEN (sq. ft.)	xxxx	xxxx
A. C. Size Depth		
90		
59		
Concrete Size Depth	xxxx	xxxx
90		
59		
LOCATE	xxxx	xxxx
Excavate & Probe (cu. ft.)		
Drill & Probe No.		
Probe & Sound No.		
EXCAVATION Hand	xxxx	xxxx
Adobe (cu. ft.)		
Adobe Wet		
Loam		
Sand		
Sand Wet		
Soft Rock		
Hard Rock		
Tunnel		
EXCAV. Machine, Kind	xxxx	xxxx
Adobe		
Adobe Wet		
Loam		
Sand		
Sand Wet		
Soft Rock		
Hard Rock		
SOD Removed (Sq. ft.)		
SOD Replaced (sq. ft.)		
BACKFILL (cu. ft.)	xxxx	xxxx
By Equip.		
By Hand		
Tamped (sq. ft. x No. Lifts)		
Jetted cu. ft.		
SPOILS LOADED (cu. ft.)	xxxx	xxxx
Hand		
Equip. Kind		
CUTBACK PLACED (sq. ft.)		
PAVING SWEPT (sq. ft.)		

EBMUD FORM R-31A

ELEMENTS	Amt.	Std.
BORES (Total ft.)		
Method		
TAPS Wet Dry	xxxx	xxxx
Size Method Type of Main	xxxx	xxxx
Copper Installed		
Size Total ft.		
Conn. to Main Cock		
Size		
Disconn. Main Cock		
Size		
Service Union		
Crimp Service		
METERS SET (Size)		
Meters Removed		
M. Boxes Set (Size)		
M. Boxes Removed		
PIPE CUT		
Method Size		
Pipe Threaded (Size)		
JOINTS (Size)		
Swedge Copper		
Solder		
Threaded		
Lead		
A.C.		
Welded		
Flange		
Burned Out		

ELEMENTS	Amt.	Std.
JOINTS RECAULKED		
PIPE LAID (No. Lengths)		
Total Ft. Kind		
Pipe Removed (No. Lengths)		
Total Ft. Kind		
FITTINGS Handled (Size)		
Hydrant Body		
" Extension 6 x ___ "		
" Ell		
Gate ___ "		
Insulating Jnt ___ "		
Reducer ___ " x ___ "		
Riser ___ "		
Sleeve Solid ___ "		
Sleeve Split ___ "		
TEE Solid ___ " x ___ "		
TEE Split ___ " x ___ "		
___ ° Ell ___ "		
Saddle Nozzle ___ "		
COLLARS Single ___ "		
" Plug ___ "		
RODS Cut ___ "		
" Threaded ___ "		
" Length No.		
CLAMPS Size		
Kind		
Painted Jnt.		
DRESSERS Size		
Style		
BLOW OFFS Set		
" " Removed		
GATE POTS Set		
" " Removed		
MARKER POSTS Set		
" " Removed		
" " Painted		
CURBS Notched		
" Painted		

ELEMENTS	Amt.	Std.
VALVES OPERATED		
Size		
VALVES Repacked		
Replace Gland Bolts		
Other Valve Repair		
HYDRANTS Repacked		
Replace Bolats Valve		
Other Hyd. Repair		
FLUSH Service No.		
" Houseline No.		
CONCRETE	xxxx	xxxx
Forms Made No.		
Concrete Mixed (cu. ft.)		
Anchors Poured		
Plaster Pipe	xxxx	xxxx
Size Lineal ft.		
Plaster Fittings	xxxx	xxxx
Name Size		
WATER Relied		
Water Pump Setup		
SHORING PLACED		
___ " x ___ " x ___ '		
Shoring Removed		
___ " x ___ " x ___ '		
BRIDGES Placed		
Kind Size		
Bridges Removed		
Kind Size		
SEWER REPAIRS		
Size		
Make Ready & Put Away		

Fig. 1. Obverse Side of Typical Job Report Form

This form, submitted by foremen of small crews for each job done, is the basis for determining effectiveness of performance. Similar forms are prepared for other crews. See Fig. 2 for reverse side of form.

reporting is done by the foreman or supervisor who is being evaluated. This raises immediate doubt as to the accuracy or honesty of the reports. It was anticipated that some of the reports would be worked out to favor the foremen making them. The system of reporting and the system of measurement, gram, reporting becomes more reliable. This approach enabled EBMUD to carry on the program without costs that would cancel all advantages to be gained from it.

Reports submitted by foremen are reviewed by a work analyst who computes earned time. Detailed reports,

INDIRECT LABOR AND DELAYS

Date	Foreman's Code	Job Number

		MEN	HRS	MHR
7	INDIRECT			
01	TRAVEL			
03	MEETINGS			
04	CLEAN TRUCK			
05	INVESTIGATE 4433			
06	NOTIFY			
07	FILL MAINS			
08	FLUSH MAINS			
09	MARK DISTRICT FACILITIES			
10	WORK ON DIST. FACILITIES FOR OTHER DEPARTMENTS			
11	SAFETY (Explain in Remarks)			
12				
13	FLAG			
14	TRAINING			
15	UNLOAD MATERIAL			
16				
17				
18				
19				
9	DELAYS			
31	RAIN			
32	WAIT FOR MATERIAL			
33	WAIT FOR EQUIPMENT, WELDER, OR OPERATOR			
34	REPAIR EQUIPMENT			
35	WAIT FOR CONSUMER			
36	WAIT FOR PIPE LOCATOR			
37	WAIT FOR CONTRACTOR			
38				
39				
40	OBTAIN MATERIAL			
41	EQUIPMENT STUCK			
42	TOO LATE FOR NEW JOB			
43				
44				
45				
46				
47				
48				
6	WORK ON JOB			

	MEN	HRS	MHRS
TOTAL CREW TIME			
OPERATORS TIME on Job			
WELDERS TIME on Job			
TRUCK DRIVERS TIME on Job			
TOTAL TIME			
INDIRECT AND DELAYS (Minus)			
WORK ON JOB			

REMARKS

Fig. 2. Reverse Side of Typical Job Report Form

All hours reported as delay or spent for indirect items are counted as earned hours at 100 per cent effectiveness.

however, were so well developed that, almost without exception, all attempts at padding were detected. The very fact that the supervisors and foremen are required to report their own work is one more good reason for taking care to lay thorough groundwork during the period of indoctrination. Once the supervisory personnel accept the pro- comparing earned time with actual time, are then prepared for each area supervisor for each of his crews, and a summary report is prepared for the maintenance superintendent (Table 1). Eventually, there will be a similar report on each section superintendent submitted to the division manager. Summaries are submitted bimonthly to

all levels of management and become tools in the hands of supervisors.

Use of Reports

Effectiveness is a function of good planning, organization, and attitude toward the job. Hence, the series of effectiveness reports are used to measure the performance of each supervisor. This is one of the most important results of work measurement of individual foremen and supervisors. Weak supervisors are easily spotted by plotting their effectiveness reports and comparing them with the average of all supervisors in their group. If a downward trend is noted, or if effectiveness is consistently below average, an effort is made to find out the reason for it. Usually, poor effectiveness is the result of improper utilization of men or poor reporting, or a combination of both. Other causes are the misunderstanding of the application of standards and, of course, incompetence or improper attitude.

After determining which of these causes is at fault, it becomes necessary for the upper level of supervision, the work analyst, and the foreman in question to work as a team to correct the situation. One example of the effect of poor supervision is shown by the solid curve in Fig. 3. It was previously recognized that the individual in charge of the main pipe crews lacked aggressiveness. An improvement noted during the first months of 1958 was the result of initial interest in the program. This was followed by a steady decline. Repeated efforts were made to work with this supervisor, with no apparent lasting effect. During September 1959, he was removed, and a concentrated effort to work with his subordinate supervisors produced the surprising trend shown during the last 3 months of 1959. It was subsequently deter-

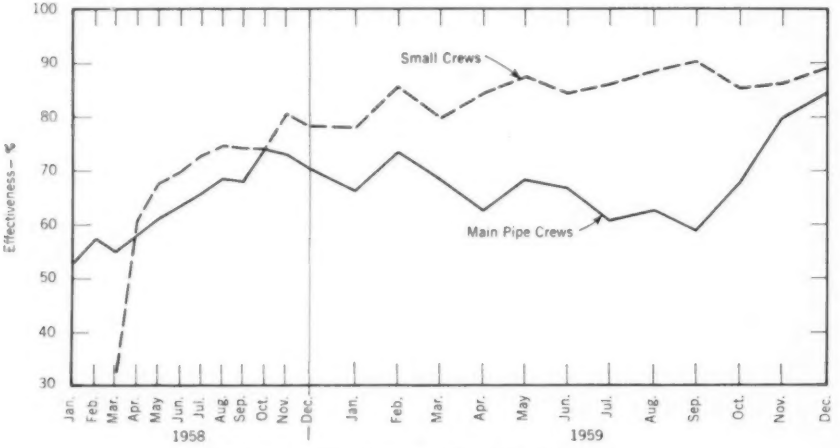

Fig. 3. Comparison of Crew Effectiveness

The steady downward trend of the solid curve during October 1958–September 1959 is an indication of supervisory weakness. Subordinate supervisors were responsible for the upward trend shown during the last 3 months of the year.

mined that the weakness of the supervisor stemmed from alcoholism, a fact not previously known by the division manager. This example is positive proof of the effectiveness of the system in spotting weak supervision and ineffective operation.

Accomplishments

As shown in Fig. 3, an increase in effectiveness is to be expected because of initial interest in the program. With this increase in effectiveness comes increased productivity. The same amount of work is found to be accomplished with fewer men, or, of course, more work could be accomplished with the original force. Management was able not only to reduce its forces by 10 per cent during the first 18 months of the program, but also to accept a larger workload. During this period, 17,500 services and 81.6 mi of distribution mains were added to the system. A large additional maintenance load was imposed by the annexation of a privately owned, substandard system of about 5,000 services. A study of the effect on unit costs shows that reductions were achieved in every category of work performed (Table 2). Furthermore, there had been no apparent reduction in total production. The amount of pipe installed during a year's period was substantially the same as that installed the year before, and the additional maintenance load had been absorbed without the necessity of an increase in force and with no deterioration in the level of service.

Annexations or an increased workload could be justifications for an increase in force. An increase in amount of pipe laid or number of services installed with no increase in force could be used in an annual report to show greater efficiency. The experienced utility manager knows, however, that there are such wide variations in conditions encountered that he cannot take a full promotional advantage of the apparent increase in productivity. He realizes that under a different set of conditions production could decrease. Additions to the working force are also approached with a reluctance that springs from doubts about the necessity for more men or about the present efficiency level. It is much more advantageous to the utility manager if he is able to point to an increased effectiveness based on a work measurement system that is recognized as an objective means of appraisal and to back this up with reference to a reduction in operat-

TABLE 1

Typical Semimonthly Report of Small-Crew Supervisors

Item	Earned Hours	Actua Hours	Effectiveness %
Direct labor			
Central area	2,265.26	2,669.82	84.8
North area	891.33	1,010.89	88.2
South area	873.21	875.08	99.8
East area	1,203.94	1,313.50	91.7
Total	5,233.74	5,869.29	89.2
Indirect labor			
Investigate	271.50	271.50	100.0
Notify	39.25	39.25	100.0
Fill mains	50.18	50.18	100.0
Flush mains	39.23	39.23	100.0
Mark distribution facilities	8.50	8.50	100.0
Work other departments	52.00	52.00	100.0
Miscellaneous	66.25	66.25	190.0
Training	36.00	36.00	100.0
Total	562.91	562.91	100.0
Delay			
Wait for material	56.26	56.26	100.0
Wait for equipment	37.26	37.26	100.0
Repair equipment	97.74	97.74	100.0
Wait for consumer	30.54	30.54	100.0
Wait for pipe locator	9.00	9.00	100.0
Wait for contractor	65.38	65.38	100.0
Miscellaneous	78.57	78.57	100.0
Equipment standby	58.17	58.17	100.0
Obtain material	39.76	39.76	100.0
Equipment stuck	51.08	51.08	100.0
Too late for new job	62.08	62.08	100.0
Crew wait, welding	53.10	53.10	100.0
Crew wait, equipment work	113.12	113.12	100.0
Lubricate or gas equipment	2.26	2.26	100.0
Move equipment	1.00	1.00	100.0
Total	755.32	755.32	100.0
Overall total	6,551.97	7,187.52	91.2

ing costs. No gimmicks need be used and no alibis need be invented.

Other Benefits

In addition to providing an evaluation of the supervisor, there are other benefits that may be derived from work measurement. New equipment or methods can be studied, justified, and evaluated by a comparison of the standard method with the method utilizing the new piece of equipment. The organization formed to establish standards for field crews may be utilized to establish similar standards for meter reading, shop, and clerical activities. Information provided by such a program can be used to assist in establishing a corporate image of efficiency of operation.

TABLE 2

*Comparison of Typical Unit Costs for Direct Labor, 1957–59**

Installations and Repairs	Annual Costs—$		
	1957	1958	1959
6-in. asbestos-cement pipe, per lineal foot	1.45	1.23	1.11
Fire hydrants, per hydrant	119.00	96.00	82.00
¾-in. tract service, per service	21.00	12.83	11.65
Cast-iron mains, per repair	54.25	52.22	47.02
Asbestos-cement mains, per repair	63.02	58.70	44.85
Service, per repair	5.96	5.30	4.79
Meters in field, per repair	1.84	1.66	1.43

* Adjusted to Jan. 1, 1957, rates.

A sincere and conscientious utility executive will always strive to establish the same efficiency in his organization as might be found in an organization in another industry. In publicly owned utilities, the elements of profit incentive and competitive spirit are not present. These incentives also seem to be lacking in some privately owned utilities. It is not intended to imply that the absence of these elements is necessarily bad, but that it is a concern of management, because rapid promotion or financial reward to supervision cannot be offered. How else can manpower be motivated to perform at peak effectiveness? Some motivation may be achieved by a striving for pride of organization, but this spirit can actually work against efficiency by fostering complacency. The element of fear can be used, but enlightened management will not consider its use.

A better expedient is to establish a spirit of competition between various units of an organization. This spirit, if properly used, is a more effective means of motivation than financial reward. The competitive spirit has been fully exploited at EBMUD through the establishment of the work measurement system, and has proved to be an effective means for increasing the supervisors' awareness of those factors in daily work that contribute to greater efficiency. No longer are supervisors complacent about the matters that affect their ratings.

Investment and Return

It is obvious that a work measurement program requires a certain amount of investment before it begins to have results. One must consider the fees of the consultant employed and the payroll costs incurred by the additional personnel required to establish and administer the program. The EBMUD project was estimated to require a $50,000 investment. A commitment, however, was made by the operating division that, after 18 months, savings from payroll reduction would amount to at least $100,000 per year. It is of interest to note the way in which this was carried out.

The consultant's fee was $20,500, including the cost of the feasibility survey. On May 15, 1957, five analysts were put on the payroll at a cost of approximately $30,000 per year. An additional payroll cost for clerical assistance amounted to approximately $4,000 per year. From the time the program was formally begun, the number of positions filled in the construction and maintenance section gradually decreased as retirements and other separations occurred, until, by January 1958, a total of eight people had been removed from the payroll of this section. At this point, the reduction in the working force balanced out the addition of the five analysts. The total investment at this time was $45,000. Payroll reductions were approximately $10,000, and the net investment was $35,000 (Table 3).

TABLE 3

Total Investment of EBMUD Work Measurement Program

Consultant's fees	$20,500
Analysts' salaries, to Feb. 1958	22,000
Clerical costs	2,500
Total	$45,000
Less: direct labor eliminated, to 1958 (estimated)	10,000
Net investment, Feb. 1958	$35,000

The program was more than paying its way. Payroll savings from the eliminated positions balanced payroll costs of the added positions, and gave a slight return. By the end of 1958, twelve additional positions had been eliminated, and the investment had been returned. From this point on, a return of more than $60,000 per year would be realized. This annual return increased with each position eliminated, until, by July 1959, the direct payroll reduction achieved was more than $100,000 per year after deduction of the analysts' salaries. To this can be added the cost of fringe benefits, to bring the actual cash savings to $115,000 per year. A 10 per cent reduction in force had been accomplished. This does not imply that at this point all efforts to increase efficiency stopped. It merely shows that at the end of the period the initial investment had been returned and that the goal, insofar as payroll reduction is concerned, was reached. Actually, the reduction has continued beyond this point, and there is still more that can be foreseen.

Summary and Conclusion

A decision to embark on a program such as that described needs:

1. The full support of management
2. At least one tenacious and dedicated individual in top management to provide motivation for the program
3. Carefully considered and established policies regulating the program's administration, reduction in force, and utilization of information
4. A complete understanding by all concerned of what the initial investment will be and how it is to be returned
5. A project that is feasible and fitted to the organization.

When a decision to proceed is made:

1. A competent, technically qualified industrial engineer must be employed to develop and maintain the program.
2. A management consultant experienced in the establishment of work standards should be retained. Although it is true that the industrial engineer himself might establish the program, more time would be required. The consultant's personnel are tran-

sient and do not add unnecessary permanent employees to the staff.

3. Enough time must be allowed for thorough training of analysts and indoctrination of supervisors.

4. The analysts must not be employed as spies. Information that they obtain, which would reflect on the competence of any supervisor, must be shared only with the supervisor involved and not passed on to higher supervision.

5. It must be expected that the standards will be assailed. Supervisors and foremen should be accorded the opportunity to share in the process of establishing standards, but once standards are established, changes should be resisted and a "show us" policy on changes adopted.

The program provides a tangible tool in the hands of management and supervision at all levels. Rewards are lower operating costs, better morale, and an effective operations force, all of which generate a public impression that the most is being achieved from utility dollars. All in all, the successful establishment of a standards system, in which one can literally watch and measure progress toward greater efficiency, is a satisfying experience.

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Connecticut and South Dakota Sections Organized

Organization of two new AWWA sections, Connecticut and South Dakota, took place during the month of April 1960, the former on Apr. 13 and the latter on Apr. 22.

Officers of the Connecticut Section are: chairman—W. Neal MacKenzie; vice-chairman—John E. Riordan; director—E. Arthur Bell; secretary-treasurer—Donald W. Loiselle.

South Dakota Section officers are: chairman—W. Plummer Wells; vice-chairman—Don Wessell; director—J. D. Davenport; secretary-treasurer—J. Darrell Bakken.

Administrative Manual of Winnipeg Engineering Department

William D. Hurst

A paper presented on May 17, 1960, at the Annual Conference, Bal Harbour, Fla., by William D. Hurst, City Engr. & Chairman of Comrs., Greater Winnipeg Water District, Winnipeg, Manitoba.

MANAGEMENT functions have been conveniently grouped into three principal components: planning, organization, and direction.[1] *Planning* is the prerequisite essential to the successful performance of duties, and involves the collection and examination of information and ideas and the casting of programs or policies to guide future actions. *Organization* is the definition of the specialized tasks of individual officers and employees, the establishment of the broad outlines of interrelationship, and the determination of the flow of authority. *Direction* is the function that involves command, coordination, and control. *Command* is the initiation of the services defined by planning and established by organization. The work program, the work order, and the rules and regulations are the principal tools of command. *Coordination* has been defined as the active modification of organization in the day-to-day work of administration. *Control* is the examination of results to make certain that all operations are carried out in accordance with the plan adopted, the orders given, and the principles laid down. In order to obtain effective communication, it is often wise to state these principal components in the form of a directive, sometimes referred to as the "administrative manual."

Measurements of Efficiency

The efficiency of the management of a water utility is often easier to appraise than the efficiency of the management of other types of municipal public works organizations. The reason for this is that a water utility is operated on the same basis as private enterprise—that is, the proof of efficiency lies in the balance sheet and the income account. Nevertheless, many water utilities form part and parcel of other municipal government activities and must often be integrated into the whole operation. This is true for the Winnipeg water supply system. The system acquires water on a wholesale basis (not under pressure) from an intermunicipal organization known as the Greater Winnipeg Water District. The Winnipeg engineering department (water system and sewerage operating branch) is responsible for the storage, treatment, pumping, and distribution of water to the consumer. The finance department of the city (water revenue branch) is responsible for the billing and collection of accounts. Because the water system operating branch is only one of several large branches of the engineering department (other branches are design, general services, inspections, sewerage, streets and traffic, street cleaning and

refuse disposal, and building maintenance), it was thought desirable to describe, for the guidance of employees, the organization, activities, and operations of the department. In many of the branches associated with the water system operating branch, the objectives are not as clear as they are in utility operation. There is no profit and loss statement to serve as a measuring rod, and the advisability of providing a certain service or degree of service is often a political decision not subject to clear-cut definition.

In municipal affairs there are many objectives. Some representatives are elected on the basis of an intense interest in social services; others for their interest in recreation, public health improvement, traffic improvement, or improvement in public works. All have different objectives, and all are striving to bring them to accomplishment. The important point, however, is not the reconciling of all the varied objectives of the various people who comprise the government of a city. Urwick [2] has well stated the problem: "The true objective of any business undertaking must be to make or distribute [efficiently and effectively] some product or service which the community needs."

Chief Administrative Officer

The ultimate aim of the head of a large department should be to insure that the funds provided in the budget for the department are used, with the greatest possible economy and efficiency, for the purposes for which they were furnished. Even for a small organization, comprising but a few persons, this aim cannot be achieved unless careful initial planning is undertaken. There must be an understanding of the responsibilities of each individual, the extent of his authority, the procedures to be followed, the books to be kept, and the records to be maintained. Also essential is a complete understanding of employee relations.

In a small organization, much of these matters of policy may either be passed on by word of mouth, taken for granted, or the head of a department may dictatorially give orders from day to day. Usually such practices lead to haphazard operations not in the best interests of management. Even for a small unit, a concise written summary covering pertinent administrative points will be worthwhile. It will provide for the automatic delegation of authority, the smoother conduct of operations, and a happier staff. It will give the department head time for planning important operations and policy matters.

The public works department of a large city is a complex structure comprising numerous branches and divisions having many diversified functions. It is the work of the head of such a department to plan and develop policies and operations, to give leadership to the department as a whole and direction to immediate subordinates, and to coordinate and control all the work of the department. For this to be successfully achieved, there must be complete understanding regarding delegation of authority; coordination of work between subheads, branches, and divisions; individual responsibilities and relationships; descriptions, qualifications, and duties of staff positions; relationships with the public; and staff administration. To brief all members of the staff properly in any way other than in writing would, at the least, result in frequent misunderstandings and inefficient work, if not in utter confusion. Staff instructions outlining the duties and responsibilities of individual positions are helpful, but they

cannot begin to cover all the organizational and administrative functions of the department. Senior members of the staff should have full knowledge of departmental functions; junior members should have some cognizance of them.

Guide for Effective Administration

The administrative manual describes and explains all the organizational and administrative features of the department, overcoming the limitations of staff instruction. The manual is a most valuable means of regulating and coordinating the operation of the department and the functions of the staff. It is thought to be of such value that, but for its size and the expense involved, it would be desirable to issue a copy to every member of the permanent staff. There is no doubt that it would be prized by many employees and would help in promoting harmonious staff relations.

Engineering Department Manual

Perhaps the best way to give an indication of the scope of a typical administrative manual would be to describe the contents of the manual of the Winnipeg engineering department. The introductory section covers the purpose of the manual and makes suggestions for its use. It provides for additions and revisions, control and distribution, and lists manuals that are both complementary and supplementary to the administrative manual. The section on the organization and functions of the department details the duties of each branch, division, and section, including the duties of the head and deputy head of the department, the chief of administration of each branch, and the deputy chief administrator. The section also deals with the relationships of standing committees of council, boards, and commissions. The section on governmental and other relationships deals with the department's relationships with the federal government, the provincial government, intermunicipal corporations, other important and related civic departments, and public and private utilities—namely, gas, electric, steam heating, transit, and the common carriers.

Winnipeg has established auxiliary units (specialty units) that serve the combined needs of all the subdivisions of the municipality. One of the most important of these is the personnel department. The manual, in the section on personnel regulations, outlines the functions of the personnel officer and his department and the procedures that must be followed with regard to filling vacancies, making appointments, persons ineligible for permanent positions, dismissals, layoffs, suspensions, hours of work, overtime, compensating time, compensation for injuries, public holidays, burials, annual vacations, sick pay regulations, pension regulations, functions of the pension board, and the welfare fund.

The section on engineering procedures deals with practices and procedures in connection with service driveways, walks and culverts, complaints, asphalt and street repairs, bridge and subway repairs, street cuts, sidewalk maintenance, snow clearing, local improvement initiation and procedure, and the flood protection plan. The administrative regulations and procedures section covers public relations, information releases, service requests, complaints, correspondence and files, and library requirements. It also deals with payrolls, staff changes, rented equipment, and collection of fees for various services, stores procedure, and equipment control.

The water works and sewerage procedures section will be of great interest to Association members. It outlines procedures and practices concerning water main and service breaks; service pipe regulations; sprinkler and special water services; services outside the city; hydrant and valve maintenance; and frozen services. It also describes sterilizing and testing of mains; turn-off and turn-on orders; meter regulations; service calls; sewer flushing, cleaning, repair, and inspection; cleaning and thawing of catch basins; gas reports; oil complaints; and duties of the office staff.

One section of the manual deals with such miscellaneous matters as snow clearing, instructions to inspectors on pavement construction, preparation of local improvement forms, alley drainage and pavement plans, acquisition of easements, establishment of building grades, and flood protection for bridges. A supplementary manual not having official status contains a digest of the city charter included for the reader's convenience. All official interpretations require a decision by the city's legal department.

Preparation and Advantages of Manual

Pioneer work on administrative manuals in Canada was undertaken by the engineering department of Vancouver, B.C. The excellent work carried out by John Oliver,[3] then city engineer, and his associates encouraged the Winnipeg engineering department to produce a similar document tailored to its needs. The deputy of the department was responsible for the preparation of the Winnipeg manual. In turn, he assigned the preparation of the various sections of the manual to the administrative officer in charge of each branch of the department to which the section referred. An enormous advantage immediately accrued. The head of every branch was literally forced to sit down and think and plan out the operation of his branch from the lowest level to the top. One of the first tasks was to define accurately the duties of each man. It is a surprising fact that most engineering administrators have never actually carried out this task. Ordinarily, the jobs developed over the years; the administrators inherited their responsibilities from a previous administrator, and, because of understandable inertia, operations were carried on as before. The result was that some men were overworked and some men underworked. A reallocation of the work load was found to be immediately necessary. The writing of the manual also forced the senior administrator to appraise thoroughly the coordination and communication in the branch and in the department. When these were found to be weak, corrective measures were taken.

The department, for years, had been considering hiring an individual whose job it would be to go over all the forms used by the department and determine whether they were *really* needed, whether they could be improved, and whether new ones were necessary to supplement the ones being used. The setting up of the manual virtually eliminated the necessity for this job. A study of forms became an absolute necessity in the writing of the manual, and many benefits resulted therefrom.

The management of the Winnipeg department has always insisted that red tape be avoided at all costs. Such delay by officials has been defined as resulting from regulations that did not arise from necessities of the job but from some individual's passion for procedure

for its own sake. The department's administrators, in writing the manual, were able to root out many instances of red tape.

Another advantage that resulted from the preparation of the manual was that once it had been prepared, it provided an incentive for a continuing study of efficient organization within the department. The manual was found to be exceptionally advantageous to the newer employees who, through reading, became familiar with the various functions and responsibilities of the officers and employees of the department. The best argument of all for the adoption of an administrative manual is that it encourages discipline. Lord Tweedsmuir, a former governor-general of Canada, defined discipline as "organized self-control." Without discipline, life becomes altogether too complicated. The administrative manual, for the reasons given, fosters and encourages business discipline.

Disadvantages of Manual

There are also disadvantages in the use of the administrative manual, the greatest one being that when something goes wrong, the excuse given is that "the matter wasn't in the book." It is impossible, of course, to cover all problems and all situations by any code of rules and regulations; indeed, one of the great burdens of present-day living is the volume of statutes, ordinances, rules, and regulations that are in effect. This great volume has, in many instances, become necessary, but what is needed in the operation of a business is integrity and common sense. Urwick, a very able business organizer, having written a complete manual of procedure for a large undertaking, inserted this final clause: "If in their practical application, any of these instructions appear repugnant to reason and common sense, let reason and common sense prevail." [2]

Conclusions

The letter of the manual must not be substituted for its spirit, and the manual must not develop a rigidity in departmental operations. The armed services are often jocularly referred to as organizations developed by geniuses capable of being operated by morons. Servicemen most likely resent such an implication intensely, but the statement is really a compliment. It simply means that everything should be designed in order that the average man can carry out his duties without having to be instructed in every task. The administrative manual, if it is well written and used properly, can provide a guide for simplicity in operation.

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Planning Distribution Storage in Nonhilly Areas

John R. Fee

A paper presented on Oct. 30, 1959, at the California Section Meeting, Bakersfield, Calif., by John R. Fee, Asst. Chief Engr., James M. Montgomery, Cons. Engrs., Inc., Pasadena, Calif.

EVERY water supply engineer who is preparing a master plan for a community's water storage facilities appreciates the advantages of a conveniently placed hill. Often, however, a hill is nonexistent or just out of economic reach, and the problem of planning for distribution storage becomes complex.

Distribution storage is necessary in order that peak demands may be served directly, either by gravity or through pumping facilities. It is not to be confused with seasonal storage, which is the impoundment of water that varies in quantity with seasonal fluctuations and the holding of it for controlled releases throughout the year.

Need for Storage

There may be a few water utility managers who believe they have more than enough distribution storage, but most of them probably wish they had more. Experience has shown that good planning in this area is essential.

Every water system that undergoes fluctuating loads needs distribution storage. The stored water may be delivered to the system by gravity, as, for example, from an elevated tank or a standpipe, or it may be pumped from a ground level reservoir, a stream, or even a ground water basin. The type of storage provided will have a material effect on the necessary storage capacity, booster pumping facilities, and associated controls.

In order to determine the proper storage capacity for each community, consideration should be given to: (1) hourly variations in water consumption in excess of the rate of inflow, (2) the reserve needed to fight a major fire, and (3) the reserve needed for a shutdown of the supply facilities for inspection and minor repairs. Determination of the amount of storage needed to provide for each of these conditions is a matter of engineering analysis and judgment.

Fluctuations in Demand

The storage required by a system to meet its normal demand fluctuations can best be determined by studying the water use records of that system—provided the records are reliable—and making careful predictions of future water use. If accurate records are not available, the experiences of other similar water systems may be used as a guide.

The demand pattern in a typical community fluctuates in a daily cycle. The low demand usually occurs about 4:00 AM and the high demand at about 7:00 PM. An example of this cycle may be seen in Fig. 1, which shows the changes in demand at Sacramento,

Calif., on a day of maximum water use. The Sacramento utility has more than 48,000 services and sells water on a flat-rate basis. The magnitude of the fluctuations is, therefore, not as great as may be expected in smaller communities or where consumption is metered.

The ordinate of Fig. 1 is expressed as a percentage of the average demand on the day of maximum water use. It can be translated into actual quantities by multiplying the percentages by the average demand. The total area under the curve represents the quantity of water required during the day. If water is pumped into the system at a constant rate equal to the average demand of the maximum day, that area beneath the curve and above the ordinate representing the average pumping rate (the cross-hatched area in Fig. 1) represents the quantity of water required from storage during periods of excess demand. Under the conditions shown in Fig. 1, this area is 16.5 per cent of the total area under the demand curve; therefore, with the water supply facilities designed to operate at a constant rate, it would be necessary to provide storage for at least 16.5 per cent of the total water requirement on the day of maximum water use.

This same storage capacity may be determined by drawing a mass diagram of the storage requirements; however, unless it is drawn to a rather large scale, an accurate graphical interpretation is difficult. If the full amount of storage requirement for fluctuating demands is not provided, it is necessary to increase correspondingly the capacity of the water supply facilities, such as treatment plants, wells, stream diversions, and water-importing facilities.

With a general idea of the minimum storage capacity required to meet fluctuating demands and to smoothen the operation of a system, the next consideration logically is what portion of the storage should be elevated. If all of the necessary storage is made available to the distribution network by gravity flow, then the booster facilities that lift the water to its elevated hydraulic gradient need be designed to pump only at the daily average rate. This is the principal advantage enjoyed by a community in a hilly area, because it usually is too costly to provide all of

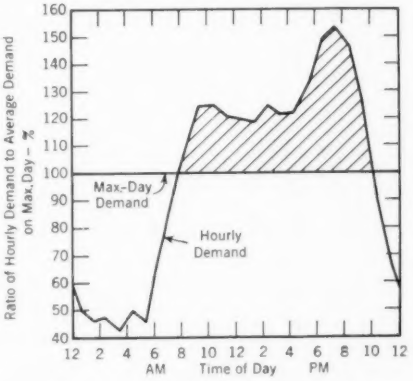

Fig. 1. Demand Fluctuations on Maximum Day

The shaded area represents the volume of water that must be provided from storage (assuming that pumping facilities are operating at capacity), in order to supply the peak demands. During off-peak hours, storage may be replenished.

the desired storage by elevated tanks, whereas it may be economically feasible to construct gravity storage at ground level if a good hill is available. On the other hand, if none of the storage is elevated, the booster facilities delivering the water to the distribution network must be capable of meeting peak demands, and the method of controlling the pumping facilities must be more

sophisticated than if elevated storage is provided.

As a rule, the first cost of booster pumping facilities is less than that of equivalent elevated storage capacity; however, as will be pointed out below, there are other factors that should be considered. If only part of the required storage is elevated, then only part of the additional boosting capacity will be needed. The ratio of elevated storage to required booster capacity is not a straight-line relationship. It is a function of the demand characteristics of the system. Figure 2 is a graph of the relationship between elevated storage and required booster capacity at Sacramento. This graph was developed from the information shown in Fig. 1. It may be noted in Fig. 2 that if all of the required fluctuation storage is elevated, then the booster capacity required will equal the average demand. Also, if no elevated storage is provided, the minimum required booster capacity is more than half again as much as is required with complete elevated storage. It should be noted that this analysis is based on peak-hour demand; with no elevated storage, the actual booster capacity requirement would be even greater because of the necessity for satisfying instantaneous demands. After all the variables had been considered, and after a detailed cost comparison, it was determined that, under the operating conditions at Sacramento, it would be desirable to provide elevated storage capacity for at least 30 per cent of the total fluctuation portion of the storage requirement. Determination of this minimum ratio was based on both economic and functional-design considerations. The principal one was the disproportionate increase in booster station requirements that would result if less than 30 per cent of the fluctuation storage were elevated.

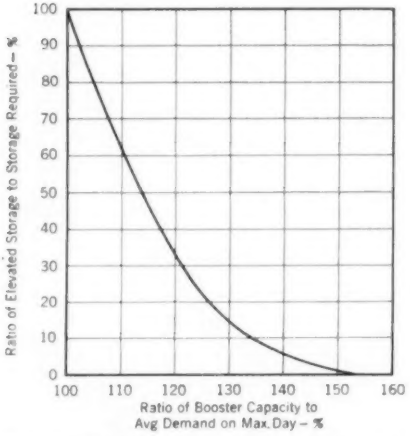

Fig. 2. Relationship of Required Booster Capacity to Elevated Storage

As can be seen, if all of the required fluctuation storage is elevated, then the booster capacity required will equal the average demand.

Fire Protection

In addition to the water required to meet fluctuating demands, a sufficient amount of water should be stored and held in reserve for fire-fighting purposes. The quantity of water required varies with the size of the city. The NBFU has developed a formula based on population for determining the recommended fire flow requirements in a community.[1] These fire flows, together with their recommended duration, may be used to calculate the recommended fire flow storage. If the booster pumping and pipeline distribution capacities are adequate, this storage may be provided at ground level.

Possible Outages

It is possible that delivery of water from the primary sources of supply

may be interrupted. Such an outage could be caused by any one of a number of circumstances: earthquake, inspection, a broken main, power failure, or even a minor repair. For this reason, it is recommended that storage capacity be provided to protect against an interruption of service during such outages. The amount of storage needed to offset outages depends entirely upon local conditions. It may vary from enough to sustain delivery for a few hours to enough for several days or weeks.

Reservoir storage capacity for outages is a form of insurance. It is a method of reducing the risk of future trouble. Just as a businessman would not buy insurance for 100 per cent coverage, it is not feasible to provide additional storage capacity to offset all possible delays caused by outages; it is, however, prudent to anticipate the need for some emergency storage and to provide for it.

Storage capacity for possible outages may be provided at ground level.

Topography

A water system in a nonhilly area usually serves only one pressure zone. If the topography of the service area has sufficient slope, or if it is desired to restrict the water from a given source to a specific service area, it may be desirable to create two or more pressure zones. When this is done, a new approach must be taken to the design of distribution storage. Such things as mutual support of water supply and storage capacity need to be considered. Booster pumping facilities may be required to deliver water from one zone into the higher one, and, with the proper facilities, it may be transported by gravity in the opposite direction. All other things being equal, it would perhaps be best to provide sufficient fire storage in the higher zone to take care of it independently; and, if there are adequate facilities to transfer water automatically from the higher zone to the lower, to provide in the lower zone the balance of fire storage required for both zones combined.

Other Considerations

Before attempting to analyze its storage requirements, one must investigate many basic aspects of a water system. Present circumstances and probable future trends in the number of services and the demand rates are important. Growth trends of the service area are important in determining the locations of reservoir sites. Elevations of the ground surface and of the buildings to be served also influence the locations of reservoir sites. The location and number of supply sources and the design of transmission mains must necessarily be considered in determining the size and location of storage facilities. Water quality is an important consideration in determining the type of storage that should be provided, for, if it is necessary to remove sand or other objectionable materials from the water, the design of the storage facilities may be considerably altered.

There are many other factors, not directly associated with the size of the system and the amount of water it produces, but these factors must be considered when planning distribution storage. Some of these are discussed below.

1. *Reliability of power supply.* In a nonhilly area it is necessary to pump the water to a satisfactory hydraulic gradient. The dependability of the power supply for these facilities will influence the amount of storage capacity and its location. Standby or alternative power sources may also be considered.

2. *Automatic control equipment.* The extent and reliability of facilities for automatically sensing and operating the system may considerably alter the needed storage capacity. Such equipment tends to reduce the need for built-in safety factors to offset human error.

3. *Reliability of water supply.* Distribution storage cannot be expected to guard against a disaster such as the necessity to abandon a well field because of salt water intrusion, but it can be designed to "stretch" the uninterrupted delivery of water to the customers during shorter periods of outages in water supply.

4. *Economics.* The availability of funds is probably the largest single factor that dictates the amount, type, and design of storage facilities. Although first cost is an important consideration, the potential value of a good investment should not be overlooked. It is not always the best policy to risk a minimum investment in order to obtain a higher rate or return, for it may only result in creating a larger expenditure elsewhere and in promoting increased customer complaints.

5. *Natural hazards.* There are areas where potential hazards, such as earthquakes, tornadoes, floods, and fires, are more prevalent. In those vicinities due consideration should be given to the design of the reservoir structure and its location. Due consideration also should be given to potential heating and freezing problems caused by temperature extremes.

6. *Aesthetics.* The appearance of reservoirs, particularly elevated tanks and standpipes, has in many instances been the controlling factor in the design of distribution storage. An unsightly tank in the center of an attractive residential neighborhood can cause considerable public unhappiness. Since World War II, the appearance of elevated-tank designs has improved considerably, with the use of smooth curves, fluted centers or sides, and tubular supports. The landscaping of a reservoir site also is important. Everyone rightly expects that the properties of a water system be well planted and maintained. If it is necessary to store materials and equipment at the reservoir site, this should be considered when planning the storage facilities. Any odors or noise that may be associated with the reservoir, also must be considered when selecting a site. The marking and lighting of an elevated tank or standpipe are also dictated by the height and location with respect to lanes of air navigation.[2]

7. *Head conditions.* An elevated tank or a standpipe must be designed for a specific high-water elevation. Therefore, in order to keep the overall height of the structure to a minimum, it is desirable to locate it at the available site with the highest ground elevation. The design of a reservoir to be constructed at ground surface may have a desired restriction in elevation in order to permit water to flow into it by gravity or to drain from it by gravity.

8. *Foundation conditions.* The soil conditions may be a factor in determining the type and location of storage facilities to be provided. If there is a high water table, the danger of floating a buried reservoir is a real problem. If piles are required, this can greatly increase the cost of a reservoir.

9. *System efficiencies.* Economies can usually be effected by properly coordinating the design of storage facilities with the design of the rest of the system. It may be feasible to reduce the connected horsepower of a

system by increasing the elevated-storage capacity and thereby reducing the required booster capacity. If the storage facilities are properly placed with respect to the distribution pipeline network, the system head losses may be reduced substantially. With adequate storage facilities it may be possible to maintain level pumping loads or to restrict most of the pumping to periods of low power demands. In order to design effectively for economies in a system, the production, storage, and distribution phases must all be studied and understood. Although it is necessary to design a system to meet peak conditions, it must not be forgotten that most of the time the system will be operating under average conditions. This is the time when most economies can be realized.

10. *Maintenance.* The expense of maintaining storage facilities can be reduced to dollars and cents, but the inconvenience of maintenance is hard to appraise. Careful consideration of the ease of maintenance should be given to the design of all facilities. If it's worth constructing, it's worth maintaining.

Alternative Types of Storage

Storage facilities for a water system located in a nonhilly area may be constructed as (1) elevated storage, (2) ground level storage, or (3) a combination of both.

Elevated storage is usually provided in the form of an elevated tank or a standpipe. This type of reservoir is more costly than one constructed at ground level, but it does eliminate the need for some of the booster pumping facilities, and it makes water immediately available to meet the demands of the distribution system. Part of the storage capacity of a standpipe is not active, but, in the event of an emergency, the water in that portion is readily available at a lower hydraulic gradient. Two general rules regarding standpipes are that they are usually uneconomical to construct if the height is more than 65 ft or if the product of the diameter and the height approaches 7,000 sq ft. Elevated tanks normally are not constructed with a capacity larger than 3 mil gal.

Ground level storage may be provided in many forms. It may be a reservoir constructed on the ground surface, it may be partially buried, or it may be completely buried. Sometimes the ground water basin from which the water is produced may be considered as storage capacity, provided that the water from this basin is present in sufficient quantity and its quality is satisfactory for direct delivery into the system, and provided that the pumping facilities are adequate and dependable.

In order to deliver water from ground level storage into the distribution system, it is necessary to provide booster pumping facilities that respond to the system demands. This can be done by using pumping facilities equipped with variable-speed motors or by selecting a family of pumps that, when operated in the right combination, can deliver the required capacity. If the system is not too large, the addition of a hydropneumatic tank.[3] may be used to smoothen pumping operations.

The combined use of elevated and ground level storage is very common. This plan proved to be most feasible at Sacramento. It was readily apparent that it would not be economically feasible for Sacramento to provide elevated storage for all of its fluctuating demand storage, but it was not obvious that

complete ground level storage would be more costly than a combination. In order to determine the latter, it was necessary to plan two completely separate water systems. At Sacramento, the principal locations of water supply points are (or will be) at approximately three locations. In order to deliver the water from these supply sources to fringe customers on the opposite side of the city, it was found to be most economical to locate elevated tanks or ground level reservoirs with local pumping facilities at those fringe areas. The exclusive use of ground level storage would have required more booster pumping capacity than a combination, and it would necessitate the construction of long, large, low-head transmission mains for delivering water from the supply sources into the outlying ground level reservoirs. On the other hand, the use of both elevated and ground level storage requires larger transmission mains operating under distribution system pressures and more costly storage facilities. After a detailed study of the alternatives, the combination proved to be more economical. In another community with a different pattern of water use and a different scattering of points for water supply and consumption, the results of such a study might favor the other method. This can only be determined by considering all of the variables and investigating each situation independently.

Conclusion

It is important that adequate records be maintained of the operations of each water system, because these histories normally are the best basis for planning future water storage requirements. In nonhilly communities, facilities may be provided to store water at ground level, or in elevated tanks, or in both. Each system must be studied thoroughly in order to judge the required storage capacity of each type of reservoir. It is necessary to consider individually every conceivable variable that may influence the design of each reservoir.

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Use of Polyphosphates for Developing Protective Calcite Coatings

Robert F. McCauley

A paper presented on Jul. 14, 1959, at the Annual Conference, San Francisco, Calif., by Robert F. McCauley, Assoc. Prof., Civ. & San. Eng., Michigan State Univ., East Lansing, Mich. This research is being conducted under the auspices of AWWA Task Group 2811 D—Protective Coatings for Water Distribution Systems, and is being supported by Research Grant 4627 from the National Institutes of Health.

THREE years ago, the author undertook a study of the development of natural protective coatings for abating internal corrosion of metal water pipe. Experiments were initiated with calcium and iron carbonates because of their wide use in water supply practice for protection against corrosion. Experimental results have been encouraging and work has therefore been continued with these materials.

In a preliminary paper discussing studies with recirculated synthetic water [1] it was reported that:

1. Carbonate coatings developed under static conditions or with low flow velocity were soft and porous compared with those from dynamic tests at medium and high velocity. Flow velocities of 1 fps or higher were required to develop useful anticorrosion coatings.

2. Better protection and better bonded, harder and tougher coatings resulted from waters containing colloidal calcium carbonate than from chemically identical waters with no colloid content. Crystals of calcium carbonate larger than colloids did not have this effect.

3. High momentary excess (ME) of calcium carbonate (pH 9.5–10.0), determined from Dye's formulations,[2] led to the development of soft, chalky calcite deposits. A low ME (pH 7.7–8.3) and high total (or saturation) excess produced the most satisfactory coatings.

4. Coating materials developed on cast iron were largely hydrous ferric oxide in the form of limonite, mixed with 5–40 per cent calcite. Ferrous carbonate ($FeCO_3$, or siderite) was often observed next to the metal.

Preliminary Experiments

Success attained in work with synthetic recirculated water with a low

TABLE 1

*Analysis of Michigan State University Tap Water**

Component	Concentration *ppm*
Calcium†	221
Magnesium†	118
Bicarbonate†	315
Carbonate	0
Sodium	8.6
Sulfates	7.1
Chlorides	6.1
Nitrates	1.7
Silica‡	15
Iron	0.3
Free CO_2	19.5
Dissolved solids	325
Total hardness	339
Dissolved oxygen	6.0

* The pH was 6.9.
† As $CaCO_3$.
‡ As SiO_2.

ME of calcium carbonate and containing colloidal calcium carbonate has suggested that a practical field method might be devised for developing permanent protective coatings in relatively short periods of time. In order to explore this possibility, studies were begun with a continuous flow of Michigan State University tap water. In a series of tests the tap water flow was divided to feed sodium hydroxide and sodium carbonate to a bypassed portion. The high, 10.5 pH level in the bypassed flow resulted in the development of colloidal calcium carbonate in that line.

Figure 1 is a flow diagram of these experiments. Bypass and main flow were mixed and then passed through a 5-gal plastic mixing drum, discharging to waste through a series of short test sections of sandblasted black iron pipe. The test nipples, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{3}{8}$, and $\frac{1}{4}$ in. in diameter, were joined in series by iron reducers. Velocities in the nipples were 1.5, 3.4, 8.0, and 13.5 fps.

The tap water used varies slightly in chemical composition from day to day, but is represented by the typical analysis of Table 1. Sodium hydroxide and sodium carbonate were fed to produce a test water with a calcium carbonate ME of 5 ppm and pH of 8.1.

In 8-hr tests, extremely hard, tough coatings of unusual protection were deposited. Good-to-excellent coatings were developed on all nipples; however, coatings of the small-diameter nipples at flow velocities of 8 and 13 fps were superior in all respects to those obtained at lower flow velocities. One small-diameter test nipple was cut lengthwise and the uncoated metal surface was painted. The pipe was then stored in oxygen-saturated water. Almost no rusting occurred through the coating during 6 months' storage, although the paint showed serious deterioration.

These initial coatings were harder and tougher than any deposits developed before or since, being fine grained and dense with a thickness of perhaps $\frac{1}{64}$ in. Some coatings were ivory-colored calcite deposits; others were mixtures of calcite and iron oxide. Although not of uniform density and thickness, most of them had high anticorrosion value.

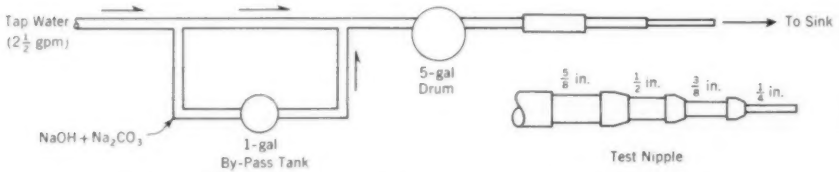

Fig. 1. Flow Diagram of Setup for Preliminary Experiments

Bypass and main flow were mixed and passed through the 5-gal plastic mixing drum, discharging to waste through the series of test nipples of sandblasted black iron pipe.

In these tests, and in all later experiments in which successful coatings were developed, the heaviest and most dense deposits were on the inlet ends of the pipe and test specimens.

Main Coating Studies

Sixty tests have been made with Michigan State University tap water for studies on black iron nipples and on 1×3-in. cast-iron specimens. In all

tests, the nipple and cast-iron specimens were sandblasted to bare metal in order to accelerate rusting.

Figure 2 is a flow diagram of the setup used for most of these tests. Usually, the velocity was 1.5 fps. The 60 runs of experiments in this work may be classified into three groups: Runs 1–7, 8–49, and 50–60.

Runs 1–7

Runs 1–7 were 24 hr in length, and no chemicals other than sodium hydroxide were added to the tap water. The tests were conducted to develop calcium carbonate colloids in the bypass flow. By use of an aspirator, all of the caustic was added to the bypass water, which then mixed with the main flow. Tests were made with and without the holding tank to determine whether aging of the treated water had any effect on coating development.

Coatings from these experiments were thin and poorly developed or altogether absent, probably because of the low flow rate (1.5 fps). Varying the percentage flow passing through the bypass line had slight effect, if any, on the coatings, so long as the bypass pH was between 9.2 and 10.5.

After each run it was necessary to clean all lines with mineral acid to remove the heavy deposits of chalky calcium carbonate which developed. "Liming" of piping, meters, and feed aspirators was a problem in both the bypass and mainflow lines.

Runs 8–49

After Run 7, the addition of both polyphosphate and sodium hydroxide was begun to permit use of a high calcium carbonate ME without attendant incrustation of pipes and feed equipment.

With 0.9–1.0 ppm metaphosphate, the ME was increased by raising the pH of the tap water. At a pH of 8.9 and an ME of 21 ppm calcium carbonate, a smooth, hard, bluish-gray coating was developed in 6 hr. The coating differed from previous deposits in its smooth texture and bluish tinge, being quite similar in appearance to the bare, sandblasted metal. Streaks and pinholes of rust were noted, but, in spite of these imperfections, it was felt that this coating material, developed in the relatively short time of 6 hr, might well be a fruitful avenue for further exploration.

Runs 9–49 represent exploratory tests made by varying the pH, calcium level, metaphosphate level, and feed rate. Table 2 is a tabulation of some of the pertinent information regarding 25 of the 49 experiments. Runs 9 and 10 were made under poorly controlled conditions and therefore are not re-

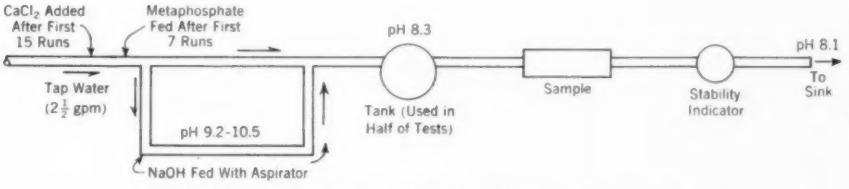

Fig. 2. Flow Diagram of Setup for Main Coating Studies

The flow velocity in the majority of the tests was 1.5 fps. Test nipples were sandblasted to accelerate rusting.

ported. The same is true of other experiments not listed—that is, except for Runs 43, 44, 48 and 49, only successful tests which developed useful coatings are reported in Table 2.

It should be noted in Table 2 that, beginning with Run 16, three chemicals were fed: sodium hydroxide for pH adjustment; calcium chloride ($CaCl_2$) for increasing the calcium level; and metaphosphate to permit maintenance of a high level of calcium carbonate supersaturation without developing chalky coatings and incrusting the piping. After Run 35, the test period was reduced to 2 hr. Table 2 also shows the total calcium carbonate excess, flow velocity in the pipe nipple, and remarks concerning the coating developed. Two columns designated as ME (momentary excess of $CaCO_3$) and DFI (driving force index) will be discussed later.

TABLE 2

*Summary of Coating Development in Runs 11–49**

Run No.	Metaphosphate *ppm*	pH	Time *hr*	Added Ca^{++} *ppm*	ME *ppm*	Total Excess *ppm*	DFI	Flow Velocity *fps*	Coating
11	0.90	8.9	6	0	28		37	1.5	light (on inlet)
16	0.20	8.9	7	14	28		40	1.5	good
17	0.20	8.8	4	20	23	64	40	1.5	good (thin in center)
21	0.07	8.8	4	18	23	38	40	1.5	good
23a	0.07	8.9	4	26	28	84	56	1.5	good
23b	0.10	8.9	4	18	28	86	52	1.5	good
25a	0.07	8.9	4	30	30	80	52	1.5	fair
25b	0.43	8.9	4	18	28	80	52	1.5	very light
27	0.86	8.9	4	36	30	88	62	1.5	light
29a	0.95	8.8	3	54	27	77	58	1.5	none
29b	0	8.8	3	50	27	77	58	1.5	good
30a	0.56	8.8	3	54	28	66	58	1.5	fair
30b	0	8.8	3	48	27	64	58	1.5	fair to good
31a	0.56	8.8	3.5	54	28	58	58	1.5	none
31b	0	8.8	3.5	48	28		58	1.5	fair
32	0	8.9	2.5	112	28		73	1.5	good, rust
34a	0	8.9	2.5	142	28	150	80	1.5	good
34b	0	8.8	2.5	90	24		58	1.5	good to fair
35a	0.19	8.8	2.5	50	24	68	50	1.5	good, rust
35b	0	8.8	2.5	60	26	70	56	1.5	good, rust
36a	0.2	8.8	2	58	26	90	56	1.5	none
36b	0	8.8	2	58	26	90	56	1.5	fair
37a	0.95	8.9	2	169	31		99	1.5	good
37b	0.50	8.9	2	169	31		99	1.5	fair to good
40a	4.10	9.6	2	208	116	218	420	1.5	none
40b	0.45	9.3	2	164	82	176	246	1.5	good
41a	2.00	8.8	2	408	31		140	1.5	good (light in color)
41b	0.60	8.8	2	408	31		140	1.5	good (coarse)
42a	3.2	9.7	2	200	150	180	461	1.5	excellent
42b	0.7	9.4	2	180	82		252	1.5	good (coarse)
43	6.5	9.4	2	420	100	488	460	1.5	none
44a†	3.0	9.3	2	264	73	144	258	1.5	none
45b†	3.1	8.9	2	1,140	35	1,038	290	1.5	light
45	2.1	8.9	2	1,056	35	1,040	270	1.5	light
46	2.2	8.9	2	1,090	35		280	3.0	good
47a	2.2	8.9	2	690	33		212	3.0	very light
47b	2.2	8.9	2	800	33		230	3.0	very light
48a	2.2	8.8	2	1,285	34		310	3.0	light
48b	2.2	8.8	2	1,285	34		310	3.0	none
49a		8.6	2	1,250	13	250	108	3.0	none
49b		8.4	2	1,250	8.0	210	67	3.0	none

* Exclusive of runs that failed to develop coatings.
† Several pipes in series of varying size gave velocities of 1.5, 3.4, 8.0 and 13.5 fps. At 8.0 and 13.5 fps, heavy calcite deposit formed but no coating developed.

In these experiments the bicarbonate–carbonate alkalinity was almost constant at the value of 315 ppm shown in Table 1 and pH level was 8.8–8.9 for all but five experiments, Runs

40–44 and 49. Calcium varied from the 221-ppm value of the tap water to 1,285 ppm in Run 48; metaphosphate was 0.00–6.5 ppm. Table 3 is a listing of those runs of Table 2 which produced the best coatings.

From Table 3, specific observations are helpful in establishing those conditions which have produced the most satisfactory coatings. Most of the better coatings were produced at an ME of 23–31 ppm, a metaphosphate level of 0.00–0.95 ppm, and a driving-force index * (DFI) 40–250. It is also interesting to note that in one instance (Run 42) an excellent coating was produced at a metaphosphate concentration of 3.20 ppm with an ME of 150 ppm. Other experiments with this high metaphosphate level and ME value, but which produced no coatings, were at a DFI lower than the 461-ppm value for Run 42.

Runs 50–60

Data from the experiments previously described suggested a new series of studies at a velocity of 3.0 fps (rather than 1.5 fps, as in most previous runs), a pH of 9.4–9.7, metaphosphate level of about 0.5 ppm, ME of ± 85 ppm, and a DFI in the neighborhood of 150 ppm. These studies are reported in Table 4 for Runs 50–60. In all eleven tests, good-to-excellent coatings were produced on sandblasted black iron pipe walls and on cast-iron specimens.

Nipples were coated with a smooth, bluish calcite deposit in all tests. Several of the nipples showed no rust at all after a 2-hr experimental period for coating development. In others, a small amount of rust could be observed in creases of the pipe walls. Such results suggest that a process has now been developed which, with further refinement, may provide the type of protective eggshell coating which has been sought by many workers in the field.

* Defined under "Sample Calculations," below.

Previous Use of Metaphosphates

Control of calcium carbonate deposits by metaphosphates was first described by Hoover [3] in 1939 after he had found polyphosphates useful for preventing the cementation of filter sand in lime softening plants and for eliminating calcium carbonate scale buildup in treatment plant lines and in distribution systems. At about the same time Rosenstein [4] used sodium metaphosphate for overcoming calcium carbonate deposition from crop irrigation water when anhydrous ammonia was used for replenishment of soil nitrogen.

TABLE 3

Data for Seventeen Best Coatings (Runs 11–49)

Run*	pH	Concentration—ppm			DFI
		Metaphosphate	ME	Total Excess	
16	8.8	0.20	23.0		40
21	8.8	0.07	23	38	40
23a	8.9	0.07	28	84	56
23b	8.9	0.10	28	86	52
29a	8.8	0	27	77	58
32	8.9	0	28		73
34a	8.9	0	28	150	80
34b	8.8	0	24		58
35a	8.8	0.19	26	68	50
35b	8.8	0	26	70	56
37a	8.9	0.95	31		99
40b	9.3	0.45	82	176	246
41a	8.8	2.00	31		140
41b	8.8	0.60	31		140
42a	9.7	3.2	150	180	461
42b	9.4	0.7	72		252
46	8.9	2.2	35		280

* Flow velocity was 1.5 fps for all runs but Run 46, which was at 3.0 fps.

As a result of Rosenstein's work, Reitemeier and Buehrer [5] investigated the inhibiting action of minute amounts of hexametaphosphate on the precipitation of calcium carbonate from ammoniacal solutions. The findings of these workers were:

1. The presence of 1.0–1.5 ppm of metaphosphate prevented precipitation of calcium carbonate from a water containing about 200 ppm calcium (as $CaCO_3$) and 160 ppm carbonate alkalinity at pH 10.16–10.62. Lower concentrations of 0.3–0.6 ppm metaphosphate did not prevent precipitation but lengthened the time required for precipitation to commence and diminished the reaction rate after it had begun. The level of metaphosphate which just prevented precipitation was termed the threshold level.

2. The presence of metaphosphate in a concentration below the threshold level promoted the formation of large, grossly distorted crystals of calcium carbonate. The distorted crystals, unlike normal rhombic calcite precipitates, tended to adhere to the glass wall of the precipitating vessel. Crystal distortion showed that metaphosphate interfered with the crystallization process; x-ray spectrogram proved the crystals to be true calcite, however.

3. When calcite precipitated in the presence of metaphosphate, the phosphate was adsorbed by precipitating calcium carbonate. For any given condition of precipitation, the total amount of precipitated metaphosphate increased with time and with the metaphosphate concentration.

4. The presence of metaphosphate was found to have no relation to the rate of conversion of bicarbonate to carbonate ions. Metaphosphates were presumed to act by restricting or deranging crystallization due to the adsorption of the metaphosphate on the crystal faces.

TABLE 4

Summary of Coating Development in Runs 50–60

Run No.	Metaphosphate *ppm*	pH	Time *hr*	Added Ca^{++} *ppm*	ME *ppm*	Total excess *ppm*	DFI	Flow Velocity	Coating
50	0.45	9.4	3	0	81		137	1.5	good, rust on seam
51	0.42	9.4	3	0	81	112	140	1.5	good, rust on seam
52	0.30	9.4	2	0	85	145	147	3.0	good, rust on seam
53	0.31	9.4	2	0	80	143	141	3.0	good, rust on seam
54§	0.02	9.5	2	0	98	116	168	3.0	coarse, fine rust
55†	0.10	9.4	2	0	87	140	148	3.0	excellent, some rust
56†	0.48	9.6	2	0	114	153	199	3.0	excellent, some rust
57	0.38	9.7	2	0	144	165	244	3.0	excellent, no rust
58‡	0.52	9.4	2	110	86	220	220	3.0	very good, no rust
59	0.87	9.4	2	120	81	170	229	3.0	very good, no rust
60§		9.8	2		175			3.0	coarse, fine rust

* Rusty water during flushing of distribution mains.
† Cast-iron sample only; no pipe nipple in line.
‡ Stainless-steel specimen also placed in line.
§ Started metaphosphate 3.80 ppm, calcium added 0.00 over 2 hr of run, metaphosphate decreased to 0.35 calcium increased to add 244 ppm.

Experiences of Rice and Hatch [6] with sodium metaphosphate were similar to those reported by Reitemeier and Buehrer. Rice and Hatch reported that 90 ppm calcium carbonate was held in solution and prevented from precipitating from a water of 400 ppm calcium hardness at 60°C by the presence of 2 ppm sodium hexametaphosphate.

Rice and Hatch found that filter sand incrusted with calcium carbonate lost

its capacity to cause after-precipitation after passage of water containing 0.5 ppm metaphosphate through the incrusted sand. It was also observed that once the sand surface was saturated with metaphosphate, an appreciable quantity of untreated water had to be passed through the sand to restore the capacity to cause after-precipitation.

More recently, Illig [7] stated that about 600 ppm calcium carbonate was prevented from precipitating at 40°C by the presence of 2.0 ppm metaphosphate. At 100°C this same metaphosphate concentration held 200 ppm calcium carbonate in solution and prevented its precipitation.

In discussing the use of threshold polyphosphate dosage, Larson [8] has noted that phosphate prevents only the development of calcium carbonate scale and has no effect on magnesium hydroxide, which may also precipitate after lime softening. Larson observed that scales in hot-water heaters usually were composed of calcium carbonate and that threshold polyphosphate treatment prevented these deposits if the retention time of the water was not more than a few hours.

The use of metaphosphate to remove corrosion products and deposits has often been attempted in practice. Hoover [3] found that a $\frac{3}{4}$–$\frac{5}{8}$-in. thick calcium carbonate scale in a lime softening plant line was reduced to $\frac{1}{4}$ in. after 25 days of metaphosphate treatment, and that after this period of usage the top $\frac{1}{8}$ in. of remaining scale was very soft. Larson,[8] however, had stated that attempts at nonmechanical removal of corrosion products and deposits other than calcium carbonate by the use of polyphosphates have often been unsuccessful and that the action of metaphosphates on various types of deposits is not yet completely understood.

Metaphosphates and Calcite Coatings

As a result of the work reported here, it has now become apparent to the author that two competing mechanisms are normally present in cast-iron water mains carrying slight supersaturations of calcium carbonate: (1) corrosion of the metal of the pipe wall and (2) deposition of calcium carbonate in the form of calcite. It has been observed that, when machined cast-iron specimens corrode rapidly, a large calcium carbonate supersaturation is necessary to coat the metal. In all instances, once corrosion has set in at some point or points on the metal, calcite deposits are difficult to develop.

In older cast-iron mains, a similar competition undoubtedly takes place between the forces tending to deposit calcite and forces tending to corrode the metal if the dissolved oxygen is more than 2–3 ppm. In experiments reported here, the 6–7-ppm oxygen level of Michigan State University tap water was observed to corrode walls of sand-blasted pipe in a few hours. Corrosion seemed to be initiated more easily under static conditions than under conditions of flow, although the difference may have been due to the removal of corrosion products by the flowing water rather than to the higher initial corrosion rate in the static tests.

Experiments have shown that the deposition of calcium carbonate coatings is a function of both pipe velocity and calcium carbonate supersaturation. Higher velocities result in better coatings. Within the limits of the normal flows in water mains in service, it would seem that the higher the velocity, the better the calcite coating.

For these reasons, the conventional practice of maintaining a positive Langelier index of 0.1–0.2 pH unit is often of slight value for reducing the

corrosiveness of a water. Both laboratory experimentation and field experience have demonstrated that a modest calcium carbonate supersaturation does not necessarily cause a useful protective eggshell coating to develop. On the contrary, this experimental work indicates that coatings can seldom be developed under the conditions of low flow velocity which are common to the smaller lines of a distribution system. These findings are in keeping with those of others who have worked on the control of calcium carbonate coatings by use of polyphosphates. For instance, Rice and Hatch,[6] writing in 1939, stated:

> The use of a thin layer of calcium carbonate scale for corrosion control appears attractive to many. Unfortunately, its practical attainment has proven difficult due to the tendency for heavy precipitation near the plant, leaving the outlying sections of the distribution system unprotected. This difficulty may be overcome by using amounts of sodium hexametaphosphate insufficient to completely prevent precipitation. "Subthreshold" treatment in this manner is already being successfully used in several municipal water plants to spread the calcium carbonate deposition throughout the system.

The present wide use of polyphosphates for scale and corrosion control in water treatment plants and in water distribution systems demands a new appraisal of several long established treatment practices. For instance, these and other investigations over the past 20 years clearly demonstrate that when water contains 0.5 ppm or more of polyphosphate, a protective calcium carbonate coating can seldom be developed by maintaining a positive Langelier index of 0.2–0.3 units at pH levels below 8.5. It is possible, and even probable, that after an effective coating of calcium carbonate has been established, the coating can be maintained or even improved at a polyphosphate level of 0.5 ppm or higher and with a slight positive saturation index. With corroding iron pipe, protective calcite coatings are established only with massive supersaturations of calcium carbonate if 0.5–1.5 ppm polyphosphate is present.

It has long been recognized that when polyphosphates are used for corrosion control in the absence of calcium carbonate coatings a high flow velocity and continuous phosphate feed are essential. For this reason, the use of polyphosphates for corrosion control in dead ends or in other areas of static or nearly static water seems to be almost useless. A similar condition holds for the development of protective calcite coatings. An effective calcium carbonate coating can, however, when once developed, be maintained under relatively static conditions.

Scale Removal With Metaphosphate

The use of metaphosphate for removing calcium carbonate scale and deposits from distribution lines has been mentioned in the literature and is sometimes attempted in practice for improving the flow characteristics of a distribution system. It would seem that such action is in error, for Larson[8] has pointed out that the wavy, rippled deposits found in distribution systems are often magnesium hydroxides, silicates, or residual alum. Calcium carbonate deposits such as the smooth-textured coatings developed in these studies are undoubtedly a very effective means for preventing corrosion and for maintaining flow capacity in iron pipes. It has been demonstrated in this work, and in practice, that calcite coatings can be developed in the presence of

polyphosphates and that these two materials, used together, are more effective than either used separately. Under certain conditions, polyphosphates may remove calcium carbonate deposits, but the circumstances under which this occurs are now most indefinite. Possibly, the conglomerate chalky deposits often laid down in systems because of uncontrolled calcium carbonate supersaturation are removed by polyphosphates, although the translucent coatings developed in this work are not removed, but can be improved with time in density and durability by the presence of the polyphosphate. Further investigation is necessary to define these important relationships.

Calcium Carbonate Supersaturation

It has been found in this work that Langelier's saturation index is not a proper measure of the forces tending to develop calcite coatings in a water line. This conventional index is a valuable indication of the calcium carbonate supersaturation or undersaturation of a water, but, because of its logarithmic nature, does not measure the actual degree of supersaturation. Ryznar's stability index is also helpful,[10] but, being empirical, it lacks exactness. More useful and exact measures of supersaturation are: (1) the total calcium carbonate excess that must be precipitated from a water for complete stability and (2) Dye's [2] ME, which is the instantaneous calcium carbonate supersaturation under any given system of temperature, dissolved solids, pH, calcium concentration, and carbonate alkalinity. Unfortunately, neither the total excess nor the ME properly measures the driving force tending to cause calcium carbonate deposition if the levels of calcium and of carbonate alkalinity (in terms of $CaCO_3$) are markedly different. For this reason, a more accurate index, the driving-force index (DFI), has been devised. It is determined by multiplying the calcium level of the water by the carbonate concentration, dividing by the solubility product constant of $CaCO_3$ corrected for temperature and dissolved solids. In determining the DFI, calcium and carbonate levels and the solubility product constant are expressed in terms of $CaCO_3$.

For a completely stable water the DFI is 1.0. The DFI is an exact measure of the tendency to deposit calcium carbonate, being a statement of the law of mass action, which defines all chemical precipitations. An example of the DFI determination is shown in the "Sample Calculations" section below.

Microscopic Examination of Coatings

Calcium carbonate coatings have been developed on sandblasted black-iron pipe nipples, and on cast-iron and stainless-steel specimens which have been described in an earlier paper.[1] It has also been found that a hard, white, coarse-grained coating can be developed by these procedures on heavily rusted iron pipe in 6 hr. When, however, coated nipples from Runs 50–60 were filled with untreated tap water and left for a few days in the laboratory, a definite "red water" appearance developed, although the amount of rust present was only a fraction of that observed in similar tests with untreated nipples.

Microscopic examination of sections of the coated iron pipe nipples and of the flat cast-iron and stainless-steel specimens has revealed pinholes in all calcium carbonate coatings developed to date. In some instances the pin-

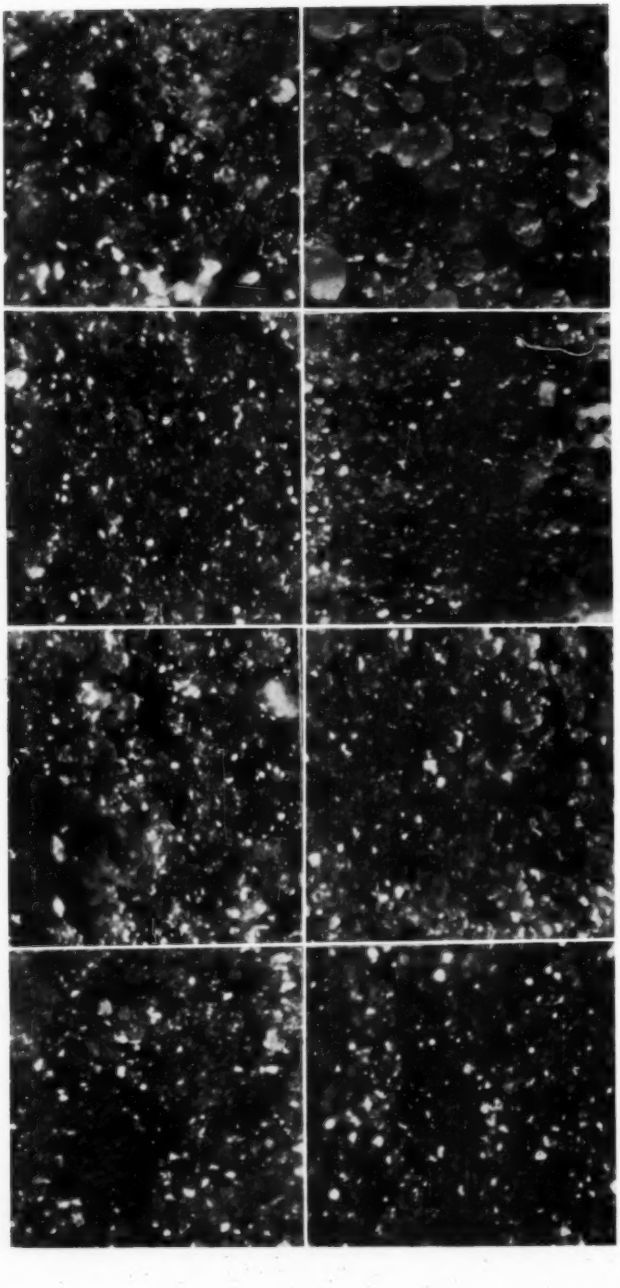

Fig. 3. Microphotographs of Test Specimens, Runs 55–60

Samples shown in the top row are (left to right) from Runs 55, 56, 57, and 58; those in the bottom row are (left to right) from Run 58 (sandblasted stainless steel), another from Run 58 (cast iron), and one each from Runs 59 and 60. Data on these runs are given in Table 4. Microphotographs are approximately 85×.

holes have been filled with rust, in others the flaw in the calcite coating has revealed clean, bare metal beneath. Coating imperfections have seemed to occur at points on the metal which developed as pits during sandblasting. In a few recent tests (not reported in Tables 2–4), which were made at a flow rate of 6.0 fps, the coatings have shown fewer imperfections.

Figure 3 shows microphotographs of eight specimens from Runs 55–60. A close examination of microphotograph shows that one deep "pot hole" of a specimen from Run 59 did not become coated with a protective deposit but corroded during the test run, producing a deep flaw. Figure 3 shows a similar defect in the coating on a stainless-steel specimen which, of course, did not corrode.

Runs 50–59 with cast-iron and stainless-steel specimens, data for which are shown in Table 4, developed uniform, translucent coatings. After the experimental tests all specimens were a bluish gray, owing to the coloration of the sandblasted metal as seen through the translucent coating. These coatings were markedly unlike the coarse calcite crystals of Run 60, which are shown in microphotograph. Run 60 was begun at a high momentary excess of 175 ppm calcium carbonate with metaphosphate present in the test water.

Hydraulic Considerations

It will be noted that the flow velocity for Runs 52–60 was increased to 3.0 fps, as compared to 1.5 fps for most previous runs. Better coatings were developed at these higher velocities, which clearly shows the importance of flow velocity in coating development. It is believed that the improved coatings formed at high flow velocities were due to the increased availability of calcium and carbonate ions to the growing crystaline surface of the coating. There may also be some relationship between the rate and type of crystal growth and the kinetic energy of the liquid.

A consideration of Reynold's number and the k/D values for cast-iron pipe (in which k is the nominal pipe roughness and D the pipe diameter) indicates that, for the nipples used in experiments described here, velocities up to 3 fps place the pipe walls in the "smooth-pipe" category of a Moody diagram.[11] An increase in Reynold's number for any given flow velocity has little effect on hydraulic roughness.

Figure 4 from Vennard [12] shows typical flow conditions which develop in laminar and turbulent pipe flow. It will be noted in this figure that, with turbulent flow in the lower velocity regions of these experiments, a thin laminar layer results next to the pipe wall. It is this laminar film which deposits the calcite coating. At high velocities, the laminar film becomes extremely thin, so that points of roughness on the pipe protrude through the laminar layer, resulting in a hydraulically rough pipe. A mathematical analysis showing that velocities of 3–6 fps should be adequate to develop hydraulic roughness has been made and included in the "Sample Calculations" section below.

By a similar mathematical analysis, utilizing Fick's law of diffusion, Romeo, Skrinde, and Eliassen [13] have shown that for hydraulically smooth pipe in turbulent flow, with water containing dissolved oxygen:

1. In pipe of the same diameter, the rate of oxygen supply from the flowing water to the corroding metal of the pipe wall varies as the 0.875th power of the velocity.

2. In flows of the same velocity, the rate of oxygen supply to the corroding metal of the pipe wall varies as the 0.125th power of the pipe diameters.

When conditions of hydraulic roughness develop, owing to disruption of the laminar layer by increased velocity or increased pipe roughness, the rate of oxygen supply is abruptly changed and depends upon velocity distribution and the mixing length. Increased velocity turbulence thus cause an increased rate of oxygen transfer.

The deposition of a protective calcium carbonate coating should follow laws identical to those which govern the corrosion of iron by a water containing dissolved oxygen. On this basis, if it is considered that the rate and uniformity of coating development depend upon the transfer rate of calcium and carbonate ions from solution to the pipe wall, a sound explanation is found for the improved coatings observed at high flow velocities. As previously mentioned, the increased kinetic energy of a highly turbulent flow may also be helpful in producing the rapid development of a dense coating.

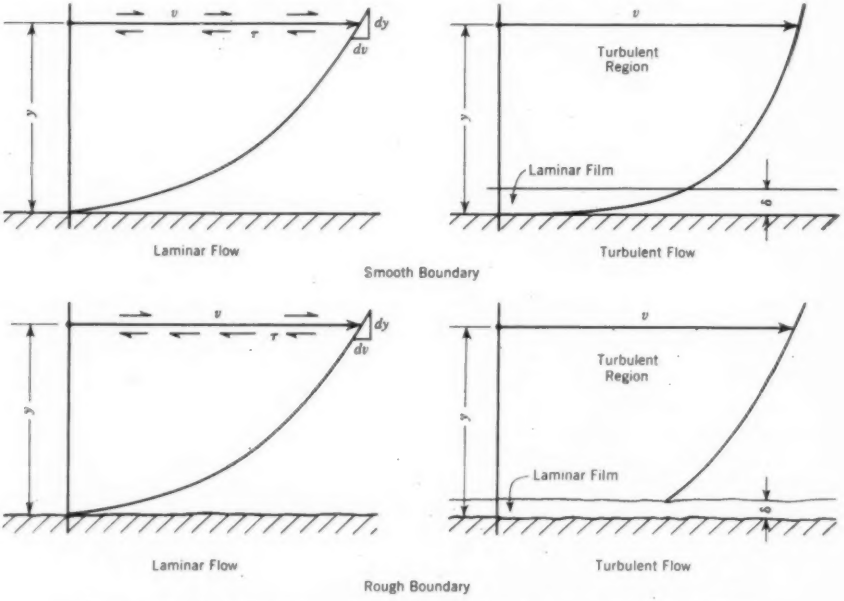

Fig. 4. Typical Conditions Developed in Laminar and Turbulent Flow

The laminar film resulting under conditions of turbulent flow is what deposits the calcite coating. This film becomes extremely thin at high flow velocities, allowing points of roughness on the pipe to protrude through it, producing a hydraulically rough pipe.

Sample Calculations

Transitional displacement velocity. The normal transition between hydraulically smooth and hydraulically rough flow is such that

$$\tfrac{1}{2} < \frac{k}{\delta'} < \tfrac{3}{2}$$

in which k is the nominal roughness of the pipe and δ' is the nominal thickness of the laminar film. It can be demonstrated that

$$\delta' = \frac{11.6\nu}{\sqrt{\tau_0/\rho}} = \frac{11.6\nu}{V\sqrt{f/8}} \quad \ldots (1)$$

in which ν is the kinematic viscosity, τ_0 is the frictional stress, V is the pipe displacement velocity, and f is the friction factor. At a water temperature of 50°F, $\nu = 1.4 \times 10^{-5}$. The friction factor, f, for cast iron is approximately 0.02. Thus, by substitution, Eq 1 becomes

$$\delta' = \frac{11.6 \times 1.4 \times 10^{-5}}{V \times \sqrt{0.02/8}} = \frac{3.2 \times 10^{-3}}{V} \quad \ldots (2)$$

By substitution for δ', the inequality expressing the region of normal transition becomes

$$\tfrac{1}{2} < \frac{kV}{3.2 \times 10^{-3}} < \tfrac{3}{2}$$

which reduces to $0.0016 < kV < 0.0048$. If $k = 10^{-3}$ ft for sandblasted pipe, then the region of transition becomes $0.0016 < 10^{-3}V < 0.0048$, or $1.6 < V < 4.8$. Thus, hydraulic roughness normally develops between 1.6 and 4.8 fps.

Momentary excess and driving-force index. For illustration, the given conditions for the sample computations to follow are: temperature, 13°C; total solids, 610 ppm; pH, 9.4; alkalinity, 420 ppm as $CaCO_3$; calcium 400 ppm as $CaCO_3$. From a nomograph in *Standard Methods*,[14] CO_3^{--} is 80 ppm, and, from a nomograph that appeared as Fig. 7 in Dye[2], the solubility product constant, K_s', is such that $K_s' \times 10^{10} = 146$ (at 13°C and 450 ppm dissolved solids).

The formula for momentary excess (all concentrations expressed in parts per million) is

$$ME = \frac{Ca^{++} + CO_3^{--}}{2} - \sqrt{\left(\frac{Ca^{++} + CO_3^{--}}{2}\right)^2 - (Ca^{++} \times CO_3^{--}) + (K_s' \times 10^{10})}$$

which, after substitution of the appropriate data, becomes

$$ME = \frac{400 + 80}{2} - \sqrt{240^2 - 32{,}000 + 146} = 79.6 \text{ ppm}$$

The formula for the driving-force index (all concentrations expressed in parts per million) is

$$DFI = \frac{Ca^{++} \times CO_3^{--}}{K_s' \times 10^{10}}$$

which, after substitution of the appropriate data, becomes

$$DFI = \frac{32{,}000}{146} = 219.$$

Conclusions

Data and qualitative observations reported here show that a useful approach to the problem of the formation of protective calcium carbonate coatings in iron water mains has been developed. The experimental data lead to these conclusions:

1. Michigan State University tap water develops hard, dense, calcite coatings on iron nipples within a few hours at velocities of 8.0–13.5 fps and a momentary calcium carbonate excess of about 5 ppm. Momentary excesses as high as 60 ppm, with a flow velocity of 1.5 fps, develop similar coatings. An uncontrolled momentary excess of more than 30 ppm results in heavy deposits of loose calcite, which vary from fine to coarse grain.

2. The addition of 0.5–1.5 ppm metaphosphate controls calcium carbonate

precipitation and permits the use of momentary-excess values as high as 100 ppm without encrustation of feed lines or piping. With a velocity of 3.0 fps, thin, translucent calcite coatings have been developed which have useful anticorrosion value.

3. Calcite coatings have been obtained with metaphosphate concentrations of 2.2 ppm and calcium levels as high as 1,500 ppm (as $CaCO_3$); however, these coatings are not superior to those obtained at lower metaphosphate and calcium levels.

4. The DFI and ME values have proved to be more useful for predicting carbonate deposition than Langelier's or Ryznar's indexes.

5. Microscopic examination of the coatings developed on sandblasted metal has shown imperfections and rusting in the translucent calcite coatings. It is believed that imperfections are at points of deep penetration by high-velocity sand grains during sandblasting.

6. Better coatings were obtained in 2-hr experiments at 3.0 fps than at 1.5 fps. In general, better coatings have resulted at high velocity than at low velocity, probably because of the decreased thickness of the laminar boundary film, more rapid mixing rate, and increased velocity distribution.

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Changes in the Streamflow Data Collection Program of USGS

Joseph V. B. Wells

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Joseph V. B. Wells, Asst. Chief, Water Resources Div., USGS, Washington, D.C. Publication of this article has been authorized by the Director, USGS.

THE basic-data collection agencies in the water investigation field have developed a "new look." The changes that have come about—although painful to some—have been the result of a real need. The use of water is growing by leaps and bounds; the basic supply is constant. An understanding of the whole complex problem of water resources has become increasingly essential. In the face of the new and more difficult problems, the information traditionally provided—on mean daily discharges, flood discharges, the occurrence of ground water, and day-to-day changes in water quality—is not enough. This information alone cannot enable water men to solve today's problems or, what is more important, to do all that should be done to alleviate the problems anticipated for tomorrow.

People in the water supply field are well aware of the problems, but they may not be so well posted on the plans of USGS and other basic-data collection agencies to furnish up-to-date tools to help solve the problems. The methods being used in exploring the whys and the wherefores in the various fields of water supply and the techniques used in presenting and interpreting the basic information are, for the most part, not new—they are, however, being refined and improved.

Some may seriously ask why a larger percentage of efforts is spent on collection, interpretation, and methods of presenting basic streamflow data when there is a need for so much more gaging-station data and so little time and money available. There has been a lot of discussion of this question within USGS, and it is now generally agreed that the change in emphasis was necessary. Agencies cooperating with USGS and other users of water quality and streamflow records played an equal part in the decision to go through with the "face-lifting" operation.

Need for Diversified Data

The extent to which streamflow data have found real applications in the solution of water problems has depended on the amount and the form of the data available. That the data have not always been adequate in amount, or in the proper form for immediate use, has not greatly handicapped development, because, until recent years, most surface water supplies in the United States have been more than adequate. For a long time, minimum flows were about the only design data ever needed. Today, however, the situation is changing rapidly and will continue to change, probably even more rapidly. Tremendous urban growth, combined with a

greatly increasing rate of per capita water use, is boosting total water requirements higher and higher. At the same time, disposal of wastes from cities and industries demands better and more complete management of water resources. The day will arrive when all major streams will have to be used to their limits, and when more and more lesser supplies will have to be developed. Designs will have to be more exact, and the investment in water projects will have to be greater. All of this will require more water data processed for direct application to the problems at hand.

USGS has developed its attack on this problem along four specific lines: (1) modifying the basic-data collection program to provide more data at more locations at more reasonable costs, (2) making basic data available in more usable form by analyzing, interpreting, and rearranging it so as to provide areal information rather than point information, (3) streamlining reporting procedures to make the information available when and where it is needed, and (4) carrying on research to develop better equipment, more and better techniques for use of basic data, and a better understanding of hydrologic principles.

Types of Gaging Stations

Throughout its history, USGS has been faced with the task of making a complete investigation of streamflow with minimum financial support. It has been necessary to stretch the available dollars as far as possible and develop acceptable shortcuts, of which the operation of the nationwide gaging station network is a good example. The network is presently composed of about 7,150 streamflow-measuring stations. Normal increases in operational funds will not keep pace with increases in the number of locations for which data are needed. It became apparent some years ago that USGS would have to develop some means of expanding its program of basic-data collection to keep up with the ever increasing demands. The plan that finally developed after much study and analysis provides for a small network of fixed primary gaging stations, movable secondary gaging stations, and water management stations where needed. The primary gaging stations will be operated indefinitely to provide a continuous record of the surface water hydrology of the United States. More complete areal coverage is provided by the secondary stream-sampling stations that are operated for 5–10 years and then moved to other sites. Records from the secondary stations are correlated with those of nearby primary stations and the data are extrapolated for longer periods. The number of secondary gaging stations in the network now totals 1,250. If it is possible to coordinate the program so that 10–20 per cent of these stations may be moved to other locations each year, it would mean an increase in areal coverage of 125–250 sites annually.

Another type of sampling is done by "partial-record" gaging stations. At these, only one or sometimes two elements of the hydrograph are recorded; for instance, the high flows, the low flows, or both. Currently, 2,100 low-flow partial-record stations and 1,960 high-flow partial-record stations are being operated. It is obvious, then, that to say that the streamflow-gaging network is comprised of 7,150 stations does not adequately describe the modern data collection program; additional

coverage is being provided by the flexibility of the secondary network and the flood and drought data collected at the 4,060 partial-record gaging stations.

Processing of Data

USGS is now providing better information for the data user. More and more attention is being directed toward furnishing the data in a form directly applicable to the solution of problems. This enables the user to proceed directly to a problem's solution without first having to make the laborious computations necessary to put the data in usable form. In the past, efforts have been directed principally toward publication of daily-discharge records. The "new look" has not reduced efforts in this important activity; on the contrary, it has led to an increase in efforts to produce useful information on water resources. This change in emphasis is best illustrated by two types of programs; namely, those of rearrangement of basic data into more usable form, and of analysis and interpretation of basic data.

Compilation Reports

The publication of a series of compilation reports is an example of rearranged basic data. These reports, one for each of the 20 regions into which the United States has been divided for convenience, include a summary of all streamflow records through 1950. The summaries include data on monthly mean discharges and runoff, as well as maximum and minimum discharges for each year of record through 1950. Thus, someone interested only in monthly data or extremes can obtain complete information for the entire period of record through 1950 in one volume, without having to go through one volume for each year, as before. In addition, the compilation reports contain data for all stations, whether active or inactive, whereas the annual "Water Supply Papers" series contains only data from those stations in current operation. Fifteen of these reports have been published and distributed; the others are expected to be in print by early 1961. In the future it is intended that compilations will be made and reports published at 5–10-year intervals.

Flow Duration Curves

Another example of rearranged data are flow duration tables and curves. These are useful in solving many water problems. Their preparation is time consuming and tedious, however, and it is doubtful that they have been used extensively by any except the large engineering firms and governmental agencies. The USGS is now compiling and publishing flow duration data as rapidly as the need develops and funds will permit. The availability of electronic computing equipment has facilitated this program. Flow duration data are now available for only a few states; it is not known when the program will be able to provide complete coverage. Flow duration analyses are carried on in cooperation with state agencies, and can progress only as fast as the states themselves desire. The flow duration program has a valuable byproduct, in that the punched tapes of daily discharge are available for other uses. USGS is abstracting two other forms of data useful in many problems: annual low flows for selected periods of days, and flood flows for selected periods. The tapes have also been loaned to private engineers and public agencies for their use in extract-

ing specific information for specific projects.

Low-Flow Frequencies

Rearranged data can be of further usefulness if arranged, analyzed, and interpreted on a regional basis. This increases the reliability of the information obtained at any one gaging station—particularly the short-term station record. For example, analyses of low-flow frequency show the probability of occurrence of specific minimum flows, provide a basis for determining the amount of storage required for a given demand, and furnish discharge data with which to appraise and evaluate the hydrology of river basins. Many of these regional analyses are already in print and are available for general use. Some have been published by the federal government and some by states as a part of the cooperative program.

Flood Frequencies

Flood frequency analyses, useful in the design of dams and water treatment plants, highway bridges, and other engineering structures, are another example of analytical and interpretative programs being carried on by USGS. These analyses, made on a regional basis, give the average recurrence interval for floods of record and relate these floods to area size and other physical factors. Such studies provide a means of estimating flood frequency and magnitude on streams for which few or no actual flow data are available. One feature of these flood frequency analyses is particularly worthy of mention—that is, the effort being made to develop historical flood information to enable a more realistic assignment of recurrence intervals to floods during the period of record. A recently completed research study on flood frequency in New England is an example. Although the actual flood record is only about 50 years long at the most, it was possible, by a diligent search of newspapers, town and county records, and diaries, to assign recurrence intervals as great as 350 years to some of the recent outstanding floods. This is important, for the difference between 50 and 350 years can have a tremendous impact on the economic feasibility of many projects. It is not possible in all areas to develop this same kind of information, because not all areas have as long a recorded history as New England. Qualitative information can be developed nearly everywhere, however, and can permit some extension of gaged flood records. Reports on flood frequency analyses have been issued largely on a state-by-state basis, because of the existing pattern of cooperation. A project is now underway to complete this work for all of the major river basins of the United States.

Flood Maps

Closely allied with flood frequency analyses and flood reporting is the preparation of maps showing flooded urban areas. The recognition of flood zoning as a possible solution of the flood problem has caused many cities to express a real need for such maps. USGS has done a limited amount of work in this field. Only one such flood map (for Topeka, Kan.) has been issued, but more are in preparation. These maps show the areas flooded by the maximum flood of record and, where practicable, the areas subject to floods of specified recurrence intervals, generally 25–50 years. The preparation of such a map requires a flood

frequency study for the stream affecting the urban area and for nearby streams. Previous regional flood frequency studies, where available, form a valuable base for on-site frequency analyses.

Research Activities

The programs of basic-data collection, rearrangement, analysis, and interpretation are closely supported by a research program. The research program has three principal objectives: (1) the development of better equipment and instruments, (2) the development of new techniques for application of water data to water problems, and (3) a better understanding of the principles governing the occurrence and movement of surface waters. Although the research program is still in its infancy, significant progress has been made. Work on better instruments to record water data has proceeded throughout the history of USGS, but it has been greatly accelerated during the past 3–4 years. The development of techniques by research is beginning to show results, also. Two of these are the regional flood frequency technique and a technique for tracing the movement of nuclear wastes in surface streams. Both are timely and of great importance.

New Instrumentation

Of particular interest in the field of instrumentation is the development of equipment to speed the processing of field data and to do it at a reduced cost. The bubbler gage, which translates hydrostatic pressure changes into a record of river stages, eliminates to a large degree the costly structures needed for the stilling wells that are necessary with the conventional float-and-pulley systems. Another important piece of equipment now in the final stages of development is the digital water stage recorder. The river stages are punched on a tape at predetermined intervals of time. As many as 96 stages may be recorded in a day on the current model. The digital recorder will largely replace the present recorder, which gives a continuous line tracing of the river stage. The tape from the digital recorder can be fed directly into an electronic computer, eliminating the laborious hand computation of daily river discharge. A relatively few hours of computer time will accomplish as much data processing as could previously be done only with many man-days or man-months of effort.

Regional Flood Frequencies

Regional flood frequency analyses have, in the past, been based largely on such simple correlations as those between flood discharge and drainage area size. The results have, in general, been useful, but it would be desirable to refine the techniques to obtain better results. Inclusion of all factors that were known to be significant was not feasible prior to the availability of electronic computers, because the cost of making multiple correlations by hand was prohibitive. Recent work on the research project on flood frequency, using New England data and an electronic computer for making correlations, shows that, where appropriate, it is now possible to include such factors as the size of the drainage area, the amount of rainfall and its intensity, winter temperatures, basin storage, slope, and orographic influences as principal variables without materially increasing the total cost. The resultant formulas are more reliable.

Movement of Nuclear Wastes

The accidental release of nuclear wastes into streams could at some time be of primary concern to the operator of any municipal water treatment plant. Little is known at present about the rate of travel of nuclear wastes in streams or the rate at which they diffuse in the stream waters. In cooperation with the AEC, USGS is carrying on research on this problem. Occasional momentary "slugs" of radioactive gold are released into streams with different characteristics to determine diffusion and travel rates as a function of the channel characteristics. These activities are, of course, rigidly controlled and offer absolutely no threat to the public health. The objective of these studies is to provide the tools to forecast accurately the degree of contamination and the time available to provide emergency supplies, if necessary.

Publications

No matter how thorough or how extensive the data collection program becomes, or how well the data are processed, the project is of no value unless the results are made available widely, fully, and promptly. USGS hopes to start the "new look" in the publications part of its work in the near future. The goal now is to begin with the records for the water year ending Sep. 30, 1961. The plan involves, among other things, some carefully evaluated shortcuts in computational procedures. It will also mean abandoning the present form of the annual "Water Supply Paper" series, which for so many years has been published on a regional basis. Under the current proposal there will be an annual publication on a state basis. A gain in time is the principal reason for adopting new publication plans. Because only one USGS district office will be involved for each publication, there can be no delays because another district is not up to date in record computation. Under the present system, as many as ten districts are included in one publication, and publication must be delayed until records have been completed by all districts. The adoption of this new system will make it possible to make the publication available within 12 months or less after the end of the water year, as compared to the 24 months it now takes, on the average. For purposes of expediting such publication as much as possible, it is proposed that some mode of publication be adopted that can function both quickly and economically. Such reports will, of course, be only of temporary value and will not have the same general distribution as the "Water Supply Paper" series. Therefore, the formally reviewed streamflow records will be summarized and republished as "Water Supply Papers" at 5-year intervals. These will comprise the permanent record of the data, and will be distributed as widely as they now are. Before any such major changes are made, however, it will be necessary to consult the users of these records on the proposals.

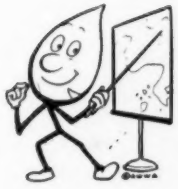
Many of the techniques employed in the surface water investigations of USGS will be made available for general use through timely and extensive publication. For example, a hydrology manual is being written and will be published. Several chapters are already at the Government Printing Office and will be published in the near future, and it is expected that other chapters will eventually be added.

The problem of keeping those in the water supply field and others advised of the availability of published reports

is still not fully resolved. USGS announces all new publications in a monthly list entitled "New Publications of the Geological Survey," but it is hardly likely that this list reaches all those who are interested. In order to help fulfill its responsibility of keeping the industry advised of new publications, USGS takes advantage of other opportunities, such as announcements in technical journals, at technical meetings, in displays at professional meettings, and by special press releases.

Conclusion

USGS has been making every effort to live up to its increasing responsibility in the solution of water problems by: (1) extending its basic-data collection program; (2) making the data more useful by rearrangement, analysis, and interpretation; (3) developing new and better techniques through research; and (4) making the results available on a timely and extensive basis. USGS has not developed this program by itself, but has consulted many of the leading engineers and hydrologists in the United States, whose assistance is greatly appreciated. USGS thinks it has a program that will stand the test of time, insofar as anyone can foretell what the future will bring. The responsibility for the successful solution of the nation's water problems must be shared equally by two groups: those who supply the basic data in such volume and in such form that it can readily be used and those who must use it. Within the financial limitations imposed on it, USGS intends to continue to meet its growing responsibility.



Water Control Progress in the Everglades

Paul D. Troxler

A paper presented on May 19, 1960, at the Annual Conference, Bal Harbour, Fla., by Paul D. Troxler, Colonel, US Army Corps of Engineers, Jacksonville Dist. Engr., Jacksonville, Fla.

SOUTH Florida and the Everglades lie in the bands of latitude, both north and south of the equator, that contain more arid land than any other similar bands on earth. Almost all of the earth's major deserts are crossed by these bands, but south Florida and the Everglades are not becoming deserts. Because of such geographic conditions as mountains and prevailing winds, which block off the rains, some of the other areas in these bands of latitude are deserts. In Florida, however, the annual average rainfall is 55 in. The rainfall in the southern part of the state is plentiful.

On the other hand, the growing period for tender truck crops in the Everglades is the dry winter season, when most of the rest of the country is too cold for such crops. Although these nonsurplus crops bring high prices, they require irrigation. The water used for irrigation is that which can be stored during periods of excess rainfall. The water is plentiful, but the seasonal distribution is poor. The Central and Southern Florida Flood Control Project is designed to prevent floods and to provide water on demand. It is neither a drainage nor an irrigation project, but a plan for water control throughout an area of approximately 15,000 sq mi.

Past Conditions

Lake Okeechobee, at the heart of the flood control project, is 730 sq mi in area. It is the second largest freshwater lake wholly within the United States. Before man-made changes were effected, this lake had no well defined outlet. The Kissimmee River, flowing in from the north, drains a 4,700-sq mi area to the lake. Other tributaries add to the inflow. In the early days, when the lake level got too high, water spilled over the entire southern rim and flowed in sheets over a broad trough southward to the tip of the mainland (Fig. 1). Centuries of this overflow, combined with decomposition of the lush vegetal cover, produced the organic peat and muck soils of the Everglades. These were thickest near the lake, gradually thinning out and being reduced in quality farther southward. The deposited soil was remarkably productive with proper water control. Soil depths of 10–13 ft exist along the southerly shores of the lake.

The availability of exceptionally rich black soil first attracted settlers to the region. Hamilton Disston, the first big developer of this area, obtained from the state 4,000,000 acres of land near the lake and extending up along the Kissimmee River. He dreamed of

great agricultural and industrial production for the area, with steamboats plying the waterways to take the products to market. The Disston empire crumbled after his death in 1896, but not until he had connected, with a canal, Lake Okeechobee to the upper reaches of the Caloosahatchee River. The lake thus had its first defined outlet to the sea.

After the turn of the century, the state of Florida developed a drainage plan for Lake Okeechobee and the Everglades. By 1928, the State Everglades Drainage District had spent nearly $18,000,000 for canals, locks, levees, and outlets from the lake (Fig. 2). The hurricanes of 1926 and 1928 ended the agency's operation when levee failures at Lake Okeechobee resulted in the loss of 500 lives in 1926 and 2,000 lives in 1928. Works of that agency had many beneficial effects, however. The Caloosahatchee River was improved, and the St. Lucie Canal was constructed to the east coast, both for lake regulation. A network of canals, constructed in the area south of the lake, provided a measure of water control, permitting a substantial economy to develop in the rich agricultural lands.

Need for Flood Control

The US Army Corps of Engineers arrived on the scene in the early 1930's. The corps was not concerned with flood control at that time and was not to be until 1936. The 1926 and 1928 catastrophes, however, were so alarming that Congress authorized substantial protective levees on Lake Okeechobee to replace and extend the inadequate ones of the earlier period. These levees and the improved outlets for the lake—made by increasing the sizes of the Caloosahatchee River and the St. Lucie Canal—were included in a navigation project for a cross-state waterway passing through Lake Okeechobee. The levees and outlets provided the control needed for safety. The canals in the upper Everglades, built by the state agency, provided enough water control for a great upsurge of development. By the 1940's, however, capacities of the canals had been exceeded. Each new development had its own encircling dikes and private pumping stations that pumped into, and further increased, the brimful capacities of the inadequate canals. Higher outside water levels increased seepage rates under the dikes, causing the need for ever greater pumping capacities. Further progress was stymied.

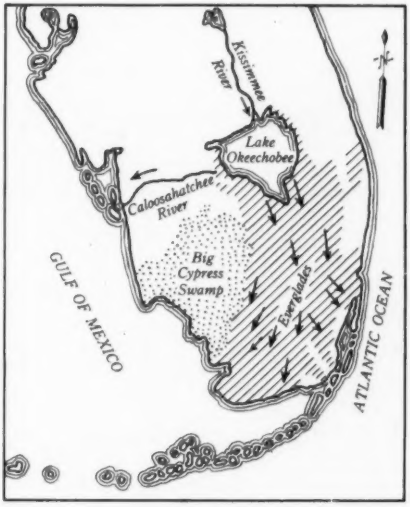


Fig. 1. Lake Okeechobee Water Flow

The Kissimmee River and other tributaries provide the inflow to the lake. In the past, when the lake level was too high, water overflowed southward, to the tip of the mainland.

In 1947, two hurricanes, with their prodigious rains, crossed the area in quick succession. It was then that 1947, already a wet year, broke the record for rainfall. At many places, the average annual rainfall more than doubled. Nearly $60,000,000 in direct losses were suffered in the project area. Cattle died; whole economies were wiped out. Water covered the produc-

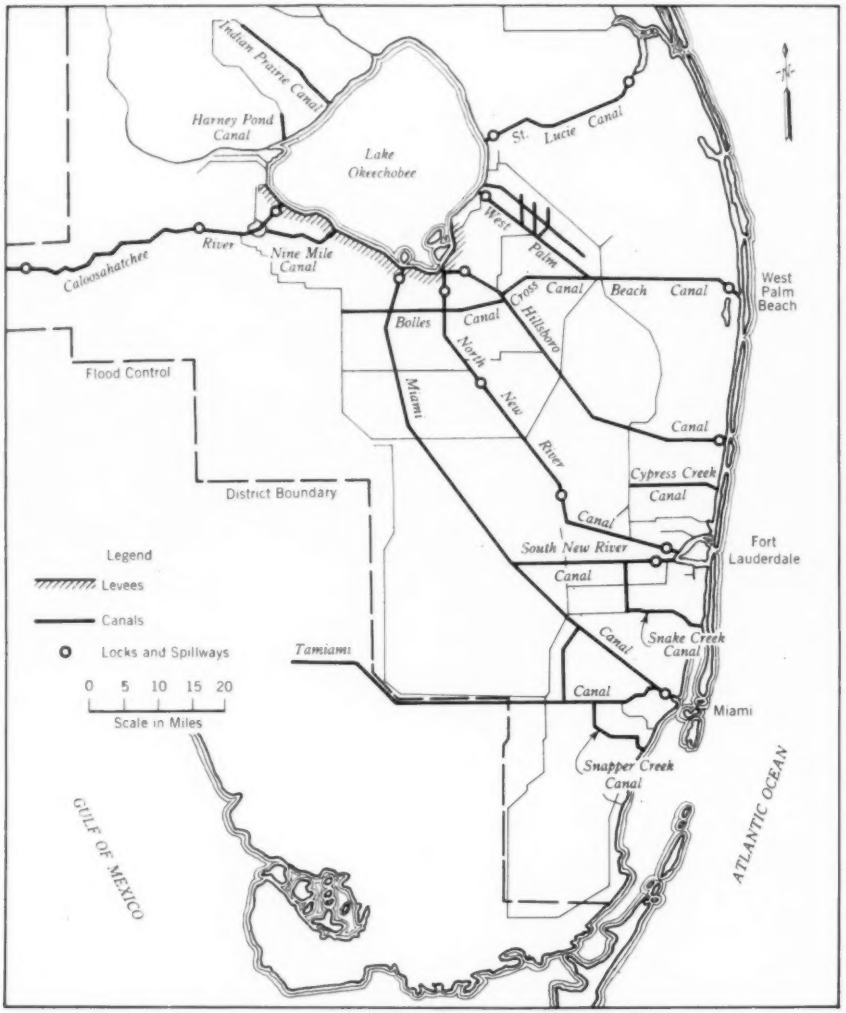


Fig. 2. Everglades Drainage District Developments, 1905–1928

By 1928, the State Everglades Drainage District had spent nearly $18,000,000 for canals, locks, levees, and outlets in the drainage project for Lake Okeechobee and the Everglades.

tive lands for months. Public sympathy was behind a solution to the water problems of the area. Congress authorized the corps to prepare a plan, which was done in a surprisingly short time for such a large order. A multimillion-dollar project was adopted by the Flood Control Act of June 1948.

Later the same year, another hurricane struck just north of Lake Okeechobee, severely damaging the cattle industry of the area. This gave further impetus to the project, with the result that construction funds were made available. Construction began in January 1950 on the line of levees protecting the urban east coast from floodwaters of the Everglades.

Fig. 3. Everglades in Flood

The Everglades is a low, monotonously flat area covered with saw grass and semi-aquatic plants.

Flood Control Project

Although the flood control project extends into the Kissimmee and upper St. Johns river valleys, far to the north, and along the entire southeastern coast of the state, this discussion will be limited, in general, to Lake Okeechobee and the Everglades. Lake Okeechobee, which spawned the fertile Everglades agricultural area south of it, is the storage reservoir from which the land is nurtured during dry seasons. The Everglades agricultural area of 1,100 sq mi is extremely flat and cannot be gravity-drained fast enough in wet seasons to save the tender crops. The old canals of the Everglades Drainage District have been enlarged to provide an adequate network near enough to all land holdings to permit effective use. Water removal is speeded by large pumping stations at the extremities of the improved canals. Some stations pump water into the lake; others pump to the conservation areas. The whole agricultural area is surrounded by protective levees.

In the dry, winter growing season, Lake Okeechobee supplies water for irrigation use by way of the same canals. The present storage capacity of the lake is adequate for present irrigation needs, but the capacity will have to be increased when development of the agricultural area advances. Thus, the range of lake levels must be increased in the near future to provide the extra water. Because this must be safely done, existing lake levees must be raised and the levee encirclement of the lake completed. The work would

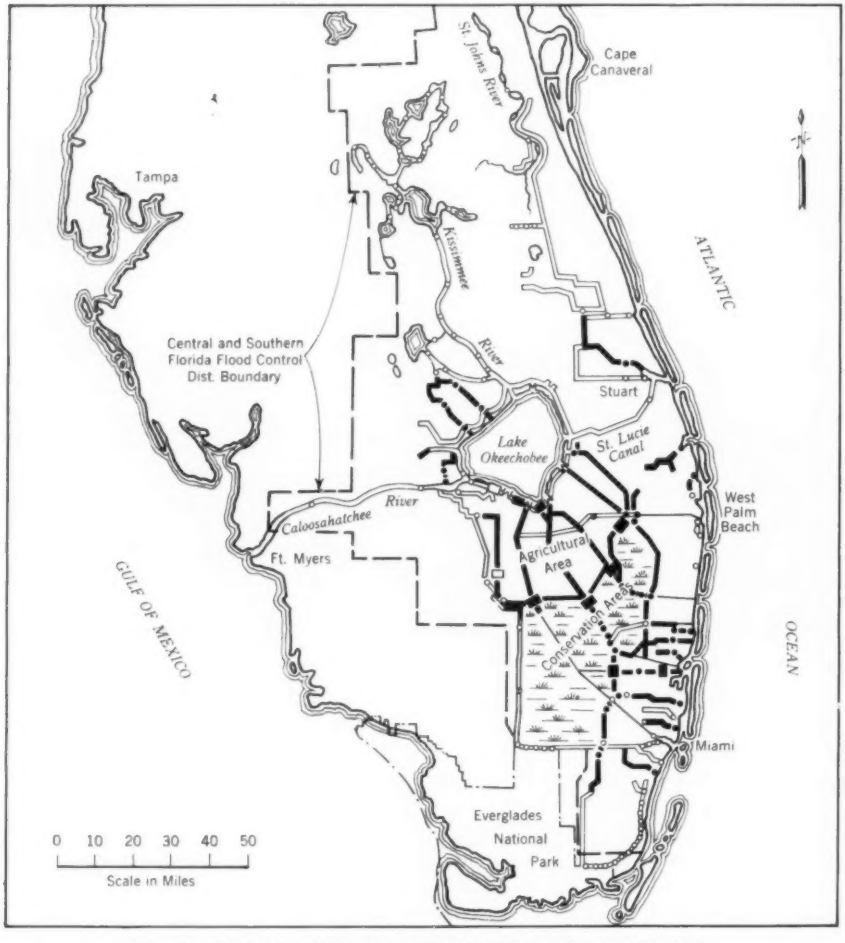


Fig. 4. Central and Southern Florida Flood Control Project

Works shown in black are those completed or under construction. The other works are to be started. Circles represent control structures; large rectangles, pumping stations; and solid and open lines, canals or levees, or both.

involve the unleveed and formerly almost uninhabited northeast and northwest shores. As storage needs become greater in future years, a larger regulatory outlet for the lake will have to be devised. Water from Lake Okeechobee may ultimately become the source of municipal supplies along the urban east coast of south Florida.

There are three conservation areas of the project, all within the Everglades and lying generally south and east of the agricultural area. These areas receive water from the agricultural area and from other westerly and northerly regions. To a limited degree, regulatory discharge from Lake Okeechobee can also be delivered by pump or gravity through the project canals after agricultural drainage has taken place. The conservation areas total 1,500 sq mi. They provide shallow storage for great volumes of water that perform many beneficial services. The land in these areas is not suited for agriculture because of the shallowness of the soil, inferior soil characteristics, and nearness to the pervious water-bearing rock that underlies it. Best use of the areas is for conservation and water retention. Water stored there is a boon to fish and wildlife, prevents Everglades fires, ameliorates temperatures in adjacent urban areas, provides fresh-water recharge for municipal well fields, supplies water to coastal agricultural areas, and preserves the conservation areas in their natural conditions. The conservation areas, right next to an area with a huge urban population, make up one of the wildest regions in North America. The appearance of the Everglades, however, may disappoint those who still have the schoolbook conception of a steaming, tangled jungle, writhing with snakes and alligators. The Everglades is actually a low, flat area covered with saw grass and semiaquatic plants (Fig. 3).

The northerly of the three conservation areas is also a wildlife refuge managed by the US Fish and Wildlife Service. The southerly two are managed by the State Game and Fresh Water Fish Commission. When these areas are filled to safe limits, excess water is released southward to Everglades National Park. There, the better water supply will enhance the aquatic biology for which the park was established.

The conservation areas will be surrounded by levees when project works are completed. The 125 mi of levees on the easterly side of the areas was the first construction accomplished. The levees protect the populous coastal region from Everglades floodwaters. In addition, these areas now drain southward, rather than eastward through the coastal urban complex as they formerly did. This keeps coastal canals unburdened by Everglades floodwaters and available for local drainage. The southward flow also helps regain the natural conditions of water movement that prevailed before man began his works there.

Financial Aspects

The project will cost about $300,000,000. Approximately $61,000,000 has been invested to date, as a joint effort of the federal government and the state of Florida. The Corps of Engineers designs, plans, and constructs the project works. The Central and Southern Florida Flood Control District, an agency of the state, represents local interests at all stages of planning and construction, provides lands, operates and maintains completed works, and contributes, in cash,

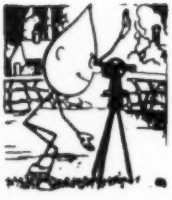
15–20 per cent of the cost of construction. In aggregate, the economic worth of the state's contribution approaches that of the federal government's. It is also interesting to note that this project is a financially sound investment. The return in annual benefits over the 50-year economic life of the project will be $4 for every $1 invested.

The flood control project is not a give-away program. In addition to the state's contribution, the individual landowners must make considerable investments to obtain full project benefits. The project provides only the basic works for water control. The individual still has to provide connecting canals to the main canals in order to receive or get rid of water on his land. He must also provide his own surrounding dikes, individual pumping stations, farm ditches, and other works so that he can adjust his water levels to his needs. The project, in effect, assures the landowner that he will have water when he needs it and a place to deposit excess water. Figure 4 illustrates the progress to date.

The pumping station on the West Palm Beach Canal is particularly interesting. It is one of the largest low-lift stations in the world, having six pumps, each nearly 10 ft in diameter. The station is capable of pumping more than 2,000,000 gpm of water during periods of flood.

Conclusions

The flood control project is a large undertaking, but the beneficial results will also be large. These benefits are even more enhanced because the production of this region is in nonsurplus commodities. Quota controls and farm subsidies are practically unknown in a region in which the principal products are beef cattle, sugar cane, fresh winter vegetables, citrus fruits, and specialized fiber crops.



Feasibility of Artificial Recharge at Newark, Del.

Catharina R. Groot

A contribution to the Journal by Catharina R. Groot, Geologist, USGS, Newark, Del.

WITH the rapid increase in industry and population in northern Delaware in recent years, it has become necessary to find ways to obtain more water from surface streams or from underground sources. This need has created a growing interest in artificial recharge as a means of increasing the natural supply of ground water in the Newark, Del., area. Conceivably, water from storm sewers or nearby surface streams could be diverted into spreading basins and allowed to infiltrate to the main ground water body. To evaluate the technical feasibility of this method of artificial recharge in the Newark area, a study of the local geologic and hydrologic conditions affecting recharge rates was made by USGS in cooperation with the city of Newark and the Delaware Geological Survey.

Previous Ground Water Studies

The first report dealing with the geology and ground water resources of the Newark area was prepared by Groot and Rasmussen [1] and published by the Delaware Geological Survey. During this early phase of the Newark area investigation, the maximum safe yield of the existing city well field known as the North Basin was calculated, on the basis of an 8-day pumping test and an appraisal of the existing hydrologic conditions, to be about 1 mgd. Also, the so-called South Basin was discovered by means of a test-drilling program and an electrical-resistivity survey.

Since 1954, the investigation of the ground water resources of the Newark area has consisted of a detailed study to explore and define the geologic and hydrologic conditions of the South Basin. This phase of the investigation will be completed after a pumping test is made with the use of the new wells that have been drilled in the South Basin area to supply additional water to the city of Newark. The test will be made as soon as the city installs pumps and connects the wells to its distribution system.

Present Investigation

This report represents the initial step in the third phase of the Newark area investigation—namely, a study of the feasibility of artificial recharge. Field work for this preliminary report was done during the fiscal year ended Jun. 30, 1959. Two infiltrometer tests were made to measure recharge rates in the North Basin area. The first infiltrometer test was made in September 1958, but the results obtained were inconclusive. Consequently, a second test was made in the spring of 1959. In addition, a test well was drilled in the North Basin area to be used as an observation well during the infiltrometer tests and to obtain cores for laboratory study. The cores were later analyzed for heavy-mineral content, grain size dis-

tribution, and pollen content in the laboratory of the Delaware Geological Survey (Table 1).

Artificial Recharge

Artificial recharge is defined as a supplement to the natural infiltration of precipitation or surface water into ground water reservoirs. It is done in various ways in different parts of the United States. The spreading of water in surface basins, furrows, pits, or ditches is the most common method used in California. In several areas in New Jersey, recharge is induced by withdrawing water from wells placed near existing rivers or lakes. A third method is used in Long Island, N.Y., where water for air conditioning is returned to the ground through recharge wells, as required by law. Since 1936, Nassau County, N.Y., has been conserving its water supply by recharging storm water into the ground through artificial recharge basins. Generally, the selection of a method depends on

TABLE 1

*Composite Log of Cored and Augered Test Holes Near Site of Infiltrometer Tests**

Material	Thickness of Layer *ft*	Depth Below Ground Level *ft*
Pleistocene series (undifferentiated)		
Sand, fine, silty, black	0.5	0.5
Sand, fine, clayey, black; mica; few small pebbles	1.5	2
Sand, fine to medium, clayey, gray; few pebbles	0.5	2.5
Sand, fine to medium, silty and clayey, gray and yellow-brown	0.5	3
Sand, fine to medium, rust-brown; little silt; considerable amount of gravel	1.3	4.3
Sand, mostly very coarse, rust-brown, rather poor sorting; very little silt and clay; some gravel	1.5	5.8
Sand, mostly very coarse, rust-brown, rather poor sorting; very little silt and clay; some gravel	2.7	8.5
Sand, medium to coarse, rust-brown and dark-brown, rather poorly sorted; some silt and clay; some small pebbles	1.5	10
Sand, fine to medium, rust-brown; little silt and clay; considerable number of pebbles	2	12
Upper Cretaceous series (undifferentiated)		
Sand, fine, clean, pink-buff	3	15
Sand, fine, clean, red-buff	0.5	15.5
Sand, fine, layering of dark-brown and light-brown and some pinkish coloring; some silt and clay	1.5	17
Sand, fine to medium, light-buff; little silt	3.5	20.5
Sand, fine, light-buff; little silt and clay	1.5	22
Water level		22
Sand, fine to medium, yellow; some silt	8.5	30.5
Sand, fine, light-buff; little silt and clay	1.5	32
Sand, fine, light-buff; some silt and clay	8.5	40.5
Sand, medium, light-buff; some silt and clay	1.5	42
Sand, fine to coarse, light-buff; some silt	8	50
Clay, gray	1.5	51.5
Clay, green and gray	13.5	65
Wissahickon schist		
Schist, weathered, dark-blue-green	18.5	83.5

* Geologic interpretation based on presence of heavy minerals.

local circumstances. In the Newark area, the spreading of water in shallow basins appears to be the most practical.

From a technical standpoint, the most important factor governing the efficiency of artificial recharge by spreading water in shallow basins is the prevailing recharge or infiltration rate. According to the US Salinity Laboratory,[2] infiltration rate is defined as the maximum rate at which a soil, in a given condition at a given time, can absorb water, ponded on the surface at a shallow depth (where adequate precautions are taken regarding border or fringe effects). It is expressed as the volume of water passing into the soil per unit of area per unit of time. This reduces to a linear unit per unit of time—for example, feet per day—as used in this article.

Generally, infiltration rates have been found to change with prolonged application of water. Typical curves of infiltration rates plotted against time are shown in Fig. 1. The characteristic S shape is explained by Muckel[3]:

a. The initial decrease in permeability or infiltration rate is believed to be caused by dispersion and swelling of the soil particles. This is much more pronounced in some soils than in others.

b. The increase in permeability following the initial decrease accompanies the elimination of entrapped air from the soil. This air is slowly dissolved in the water passing through the soil.

c. The gradual decrease in permeability that follows is due primarily to biologic activity in the soil.

Newark Experiments

Two locations in the Newark area were considered for infiltration experiments: the area around the newly acquired well west of South College Ave. and the area east of the Academy St. well field (Fig. 2). The latter site was chosen for this experiment because well logs for that area revealed the presence of a continuous body of coarse sand from 3 ft below the land surface to the water table, 22 ft below the land surface. The site was prepared by digging a pit to remove the silty material at the surface and expose the coarse sand. The minimum depth of the pit was 3 ft.

Basic to the test was the assumption that the infiltration rate indicated by an infiltrometer would be approximately equal to the rate of infiltration from a recharge basin at the same site. This

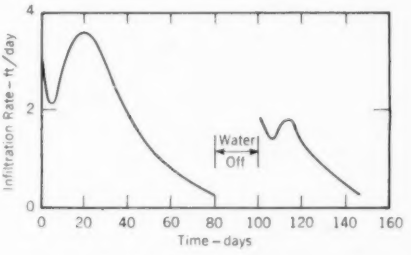


Fig. 1. Typical Infiltration Curves for Test Ponds in Kern County, Calif.

Generally, infiltration rates have been found to change with prolonged application of water, resulting in an S shape for infiltration-time curves.

assumption may not be entirely valid; if there is a difference, the infiltrometer will probably indicate a rate higher than that of infiltration from a basin. Nevertheless, it is believed that the infiltrometer test will give a correct answer, at least to the extent of indicating the possibility of artificial recharge by means of a basin.

A double-ring infiltrometer was used to determine the infiltration rate (Fig. 3). It consisted of two cylindrical rings, an inner ring 18 in. in diameter and an outer ring 24 in. in diameter. The infiltrometer was placed in position by the insertion of the base of the rings

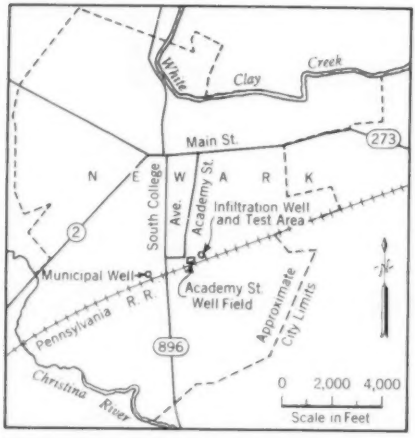


Fig. 2. Site of Infiltration Experiments in Newark Area

The site east of the Academy St. well field was chosen because well logs for that area revealed the presence of a continuous body of sand from 3 ft below the land surface to the water table, 22 ft below the land surface.

into the ground to a depth of 6 in., the smaller ring being centered within the larger one. While in use, both rings were filled with water to a height of 6 in. above the surface inside the rings, and the water level was maintained by a continuous inflow of water from an outside source. The infiltration rate was calculated from the rate of inflow to the inner ring, but the head was maintained in the outer ring to prevent the water of the inner ring from spreading laterally in the soil. Thus, the water from the inner ring was assumed to move almost vertically downward until it reached the water table.

During a preliminary infiltration test in the autumn of 1958, a double-ring infiltrometer was obtained from the Denver Hydrologic Laboratory of USGS. At that time, attempts to insert the rings into the ground to the required 6-in. depth were unsuccessful because pebbles were encountered, and the base of the rings was not sufficiently strong to break or move the pebbles aside. Consequently, the results of this test were considered unreliable.

Additional tests were made in the spring of 1959, using a more durable set of infiltration rings. A pit was dug to an average depth of 3.9 ft, and the rings were carefully worked down to the required 6-in. depth, by advance trim on the outer edge of the soil, without disturbing the soil of the inner ring. Also, an observation well was drilled near the pit to obtain information on water level for use in evaluating the effects of infiltration on the water table. In order to have a constant head of water in the infiltrometer rings, float valves were installed in each ring, and water was siphoned into the rings by separate hoses leading from two 55-gal drums. The drums were filled periodically and calibrated to measure the amount of water supplied to each ring.

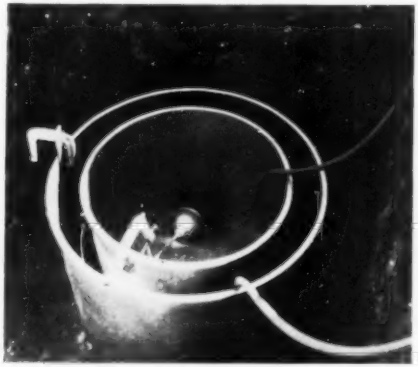


Fig. 3. Infiltrometer Rings in Place

A float-operated valve maintains the depth of water at approximately 6 in. Both rings are constructed of ¼-in. hot-rolled steel plate, with reinforcing rings welded to the top. Two 55-gal drums are used as storage tanks to supply water to the infiltrometer rings.

The test started the day after cessation of heavy rains, when the ground was nearly saturated with water. The results of the test are shown in Fig. 4. The infiltration rate of water through the inner ring did not show the initial downward gradient of the typical S curve shown in Fig. 1. Instead, the rate rose rapidly during the first 4 days of the test, from an initial 2 ft/day to more than 8 ft/day. On the fifth day, the infiltration rate declined steeply, and then declined more gradually until the eleventh day, when the supply of water to the rings was interrupted for 15 hr. After this interruption, the soil surrounding the infiltrometer was dry, and the typical S curve did appear. This seems to indicate that when the soil around the infiltrometer is not near saturation, the graph obtained is similar to that shown by Muckel (Fig. 1).

The apparent infiltration rate during the first 10 days included evaporation from the water between the rings and in the tanks, which were not covered. The tanks and rings were covered after May 8 to reduce evaporation and to prevent any addition of water by rainfall. Flocculent iron oxide from the water used in the test settled on the soil surface within the rings and formed a partial barrier to the downward movement of water. On May 20, the sediment was stirred up to see what effect this would have on the infiltration rate. As shown in Fig. 4, the rate increased for a few hours and then tapered off.

The water level in the observation well did not rise a measurable distance in response to the infiltration, even though the horizontal distance between the center of the rings and the well was only 5.2 ft, and the depth to the water was 22 ft. Presumably there was no ground water mound under the infiltrometer, because the transmissibility of the aquifer was large enough to enable discharge by lateral flow of most of the water that was recharged through the 18-in. ring at the head maintained.

Another method was tried to determine whether the water from the infiltrometer reached the water table. Fluorescein dye was placed in the inner ring of the infiltrometer; thereafter,

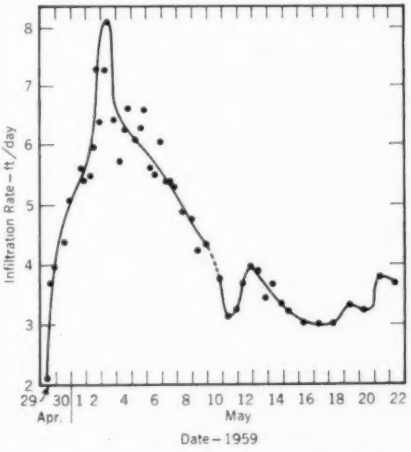


Fig. 4. Infiltration Rate at Newark

The tanks and rings were covered after May 8 to reduce evaporation and prevent the addition of water to the rings by rainfall. The supply of water to the rings was interrupted for 15 hr on May 9, shown by the dashed portion of the curve. On May 20, the sediment on the bottom of the rings was stirred up and the effect on the infiltration rate noted.

samples of water were collected from the observation well. Fluorescein ($C_{20}H_{12}O_5$), a reddish substance, imparts a yellow-green color to water under natural light and fluoresces under ultraviolet light. Ordinarily, its presence in water can be detected in solutions as dilute as 0.025 ppm with the naked eye and 0.0001 ppm with the

aid of a fluoroscope. No fluorescein, however, was detected in the water in the well, possibly because of natural discoloration of the water caused by small amounts of iron dissolved and suspended in the water, or because the samples were not inspected under ultraviolet light.

Infiltration Rate

From a study of nearly 40 published articles, it was found that an infiltration rate of 2 ft/day is considered to be an acceptable rate for recharging reservoirs.[4] In view of this, the minimum rate of 3 ft/day obtained in the 24-day test in Newark appears to be very favorable. Although it is possible that this rate may decrease with time, it is anticipated that the long-term average rate will exceed the acceptable rate of 2 ft/day.

A few calculations will demonstrate that artificial recharge is feasible at an infiltration rate of 2 ft/day. The area available is small, but an infiltration basin measuring 300×300 ft, or 90,000 sq ft in area, dug 5 ft deep, would hold about 3.4 mil gal. At a rate of 2 ft/day, about 1.3 mgd would filter into the ground. When the water reached the water table, it would move toward the well field or to other areas of discharge. Natural ground water movement is toward the southeast, beneath the shallow watercourse that now drains the area. It is conceivable, however, that much of the infiltrated water would move to the well field because of pumping, but this would not be determinable until data could be collected in the well field and a map prepared of the water table showing the depressed water surface (cone of depression) surrounding the wells. To prepare such a map would require data from a number of observation wells related to a common datum plane.

If only half the 1.3 mgd reached the well field, it would sustain pumping at a continuous rate of 450 gpm. The impounding basin, however, with only 3.4 mil gal of storage capacity, would be dry in less than 3 days at the assumed infiltration rate of 1.3 mgd.

Runoff from storm sewers would be so intermittent that an infiltration basin having only a 3-day storage capacity would be dry much of the time. This fact leaves two alternatives: to dig a deep basin, with sufficient storage capacity to provide water between periods of runoff, or to refill the basin from another surface water source. The first alternative does not seem practical, inasmuch as dry spells of 14 days or more are relatively frequent, and the water table is not deep enough, nor the available area large enough, to permit digging a basin of the required capacity.

The second alternative entails diverting enough raw water from the Christina River or White Clay Creek to refill the basin every 2 or 3 days. The water could be taken from primary settling basins at the source, to avoid excessive turbidity. A pipeline approximately 1.2 mi long would be necessary from the nearest point on either stream. As the altitude of the infiltration basin is 5 ft above the altitude of the nearest point on the Christina River and 35 ft above the altitude of the nearest point on White Clay Creek, pumps would be necessary to force the water through the pipelines.

Conclusions

Because of the test described, it is believed that the infiltration rate of the coarse sand that occurs at a depth of 3 ft below the surface at the test site is sufficient to allow large amounts of water to be absorbed and added to the ground water reservoir serving the North Basin well field. This additional

water would be filtered by the time it reached the producing wells. To obtain more specific information before large-scale operations are undertaken, it would be wise to make additional tests by spreading a larger amount of water over a greater area than was done in the test described in this article, because the infiltration rate that was obtained (3 ft/day) might not prevail when water is impounded on a larger scale.

One method of conducting a large-scale test would be to dam the storm ditch that runs alongside the testing area at a site near the culvert beneath the Pennsylvania Railroad, where the banks of the ditch come close together. Water supplied from the well field could be discharged into a small overflow ditch that runs to the storm ditch. By the volume of water spread in the ditch, and the time it takes to disappear, an infiltration rate for the larger ditch area would be obtained. The test should last for at least 20 days, in consideration of the type of curve obtained in Fig. 4, and should be continued for an additional 20 days. Correction for evaporation should also be made.

Simple observation wells could be driven to the water table around the experimental ditch, and also on the south side of the Pennsylvania Railroad, to determine changes in water level. Moreover, the analysis of the test results would be simplified if pumping in the well field were kept steady during the test. Maps of the water table before, during, and after the test would reveal the effect of the additional recharge on the local water table.

Summary

The increased demand for water in the Newark area of northern Delaware has created a growing interest in artificial recharge as a means of increasing the available supply of ground water. Presumably, water from storm sewers or nearby streams could be directed into spreading basins and allowed to percolate downward into the local ground water reservoir.

To determine the feasibility of this method of artificial recharge, a 24-day infiltrometer test was made in the vicinity of the city's principal well field. During the test, the infiltration rate, as indicated by the infiltrometer, decreased from an initial maximum rate of 8 ft/day to a minimum of 3 ft/day. Nevertheless, the minimum rate is still well above the acceptable minimum of 2 ft/day, which is considered necessary for the efficient operation of a spreading basin. Consequently, on the basis of the assumption that the infiltrometer rate is a reasonably close approximation of the rate of infiltration from a recharge basin, it appears that the infiltration rate in the vicinity of the well field now in use by the city of Newark is sufficiently high to warrant consideration of water spreading to increase local water supplies.

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Strontium-90 in Surface Water in the United States

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A paper presented on Apr. 5, 1960, under the sponsorship of AIWA, at the Engineers Joint Council's Nuclear Engineering and Science Congress, New York, N.Y., by Conrad P. Straub, Chief, Radiological Health Research Activities; Lloyd R. Setter, Chief, Radiological Investigations; A. S. Goldin, Chief, Radiochemical Analyses; and Paul F. Hallbach, Asst. Chief, Radiochemical Analyses, all of Radiological Health Research Activities, Div. of Radiological Health, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE National Water Quality Network was initiated on Oct. 1, 1957, to obtain long-term information on changes in the quality of surface waters and to provide useful data on water resources.[1] One of the analyses performed on each of the 55 samples submitted weekly is the determination of gross beta radioactivity.

After the 1-liter samples are received at the laboratory, an aliquot is passed through a membrane filter to separate the suspended and dissolved fractions.[2] This separation provides information on the degree of removal that may be expected from such water treatment processes as coagulation, sedimentation, and filtration which will remove particulate material. Gross activity levels in surface waters have been reported for the period Oct. 1, 1957–Sep. 30, 1958.[1] More extensive data on the levels of activity in the Missouri-Mississippi river basins during the first year of study were published recently in the JOURNAL.[3]

Gross activity determinations are informative in evaluating long-term trends or changes in water quality, but, by themselves, they are of limited value in assessing potential radiation exposure to man and his environment. To assess this potential hazard, a knowledge of the specific radionuclides in water is needed. As is so well known, Sr^{90} is the most significant and hazardous man-made radionuclide encountered in the aquatic environment at the present time. For this reason, the Sr^{90} content in water resources, the Sr^{90} contamination of air and the food of man and animals, and exposure due to external sources are of importance.

The significance of Sr^{90} levels in the surface waters of the United States will be discussed. The data represent a rather extensive study, in that samples were collected weekly from one to eight stations on each of fifteen major river or lake systems throughout the United States.

Previous Data

The USAEC Health and Safety Laboratory has summarized much of the existing information on Sr^{90} levels in surface and tap waters.[4–6] Recently, the British also released some results

on strontium in the surface and ground waters of England.[7] The data from these sources, summarized in Table 1, show variation in the strontium content of water with time.

Data on Sr^{90} in precipitation have been recorded for several locations in the United States for a number of years.[4-6] These and British data[7,8] are shown in Table 2. The total and dissolved strontium levels found in precipitation samples at Cincinnati were composite sample of about 4 liters. These samples were then analyzed for Sr^{90}, with the use of procedures previously described.[9,10]

Results

The Sr^{90} levels found in four series of composite samples, representing the periods Oct. 1–Dec. 31, 1958; Jan. 1–Mar. 31, 1959; Apr. 1–Jun. 30, 1959; and Jul. 1–Sep. 30, 1959, are shown in Table 4, along with average

TABLE 1

Activity of Sr^{90} in Water Environments

Source of Sample	Date*	No. of Observations	Activity—$\mu\mu c/l$		
			Mean	Median	Range
Mississippi River	Feb. 1953	1	0.13		
	Apr. 1953	1	0.09		
	May 1957	6	0.62	0.58	0.46–0.91
	Oct. 1957	3	0.76	0.80	0.59–0.89
Missouri River	Oct. 1957	1	0.25		
Richmond, Calif., reservoir	May 1958	5	0.32	0.32	0.18–0.56
British river†	Sep. 1958	3	0.32	0.26	0.25–0.44
	IV 1958	3	0.23	0.26	0.15–0.29
	I 1959	3	0.19	0.22	0.11–0.25
	II 1959	1	0.18		
British lakes†	Sep. 1958	1	0.62		
	IV 1958	8	0.44	0.40	0.35–0.60
	I 1959	7	0.43	0.40	0.36–0.60
	II 1959	1	0.85		

* Roman numerals represent quarters of the year: I, first quarter; II, second quarter; III, third quarter; and IV, fourth quarter.
† Finished waters taken from these sources.

16.2–1,045 $\mu\mu c/l$ and 14.2–810 $\mu\mu c/l$, respectively (Sr^{89} and Sr^{90}). Levels of Sr^{90} obtained by the Cincinnati group from Coast Guard and private cistern waters are shown in Table 3.

Analysis of Surface Water

Aliquots of the 1-liter samples were taken for gross activity measurements, and equal residual portions of the weekly samples from each station were combined into a 3-month (13-week) total and average dissolved gross beta activity levels. Figure 1 shows the difference in activity levels among the four series plotted on log probability paper. The activity of Sr^{90} for Oct. 1–Dec. 31, 1958 (six samples) was in the range of 0.3–1.0 $\mu\mu c/l$ of water; for Jan. 1–Mar. 31, 1959, 0.0–4.7 $\mu\mu c/l$; for Apr. 1–Jun. 30, 1959, 0.1–4.8 $\mu\mu c/l$; and for Jul. 1–Sep. 30, 1959, 0.2–3.8 $\mu\mu c/l$. The corresponding geometric mean values (excluding the

TABLE 2

Activity of Sr^{90} in Precipitation Samples

Location	Date*	Activity	
		mc/sq mi†	*μμc/l*
Lemont, Ill.	1957[4]	5.80	
	1958[5]	12.42	7.42
Birmingham, Ala.	Apr.–Dec. 1957[5]	5.45	
	1958[5]	10.38	3.75
Salt Lake City, Utah	1957[4]	12.75	
	1958[5]	9.60	
Vermillion, N.D.	Apr.–Dec. 1957[4]	9.18	
	1958[5]	9.86	9.65
W. Los Angeles, Calif.	Dec. 1956–Dec. 1957[4]	4.94	
	1958[5]	4.93	4.86
	Jan.–Mar. 1959[6]	4.63	
Coral Gables, Fla.	Apr.–Dec. 1957[4]	5.51	
	1958[5]	13.75	3.35
Westwood, N.J.	Jul.–Dec. 1957[4]	4.78	
	1958[5]	15.51	5.53
	Jan.–May 1959[6]	16.39	
Lemont Geological Observatory, N.Y.	Dec. 1953[4] (1)		0.343
	1954[4] (31)		1.54
Richmond, Calif.	Mar. 20–Dec. 31, 1958[5] (20)	5.26	6.11
	Jan.–Apr. 1959[5] (8)	3.68	7.10
Chicago, Ill.	Jun.–Dec. 1957[4]	3.88	
Pittsburgh, Pa.	Feb.–Dec. 1955[4]	7.30	
	1956[4]	9.65	
	1957[4]	6.88	
	1958[5]	12.09	4.0
	Jan.–Apr. 1959[6]	10.98	
New York, N.Y.	Feb. 1–Dec. 31, 1954[4]	7.06	
	1955[4]	6.03	
	1956[4]	11.65	
	1957[4]	11.53	
	1958[5]	15.81	5.89
	Jan.–May 1959[6]	11.79	
Louisville, Ky.	Sep. 18–Dec. 31, 1958[5]	1.965	3.54
	Jan.–Jun. 1959[6]	14.20	
Milford Haven, England	1957[8] (12)		3.94
	1958[8] (12)		5.33
All sampling stations, England	I 1957[8]		3.0
	II 1957[8]		5.8
	III 1957[8]		2.7
	IV 1957[8]		2.1
	I 1958[8]		3.6
	II 1958[8]		7.75

* Roman numerals represent quarters of the year: I, first quarter; II, second quarter; III, third quarter; and IV, fourth quarter. The superscript numerals pertain to the references at the end of the article which are the sources of data. Numbers in parentheses represent the number of observations made.

† Total activity deposited during interval indicated.

first series of only six samples) were 0.91 $\mu\mu c/l$, 1.42 $\mu\mu c/l$, and 0.72 $\mu\mu c/l$.

As a part of other studies, Sr^{90} determinations have been made on waters from the Animas River,[11] the Mohawk River, and the Delaware River. These values are summarized in Table 5 and may be compared with values reported in Tables 1 and 4.

Deposition of Sr^{90}

Strontium-90 in the environment is derived from three sources: fallout, fission product wastes from the atomic energy industry, and residues from the use of Sr^{90} for beneficial purposes. With few exceptions, substantially all the Sr^{90} currently found in the environment comes from fallout. Estimates of Sr^{90} activity from this source can be determined from a knowledge of the Sr^{90} in precipitation samples collected at many sampling stations. Soil data similar to those obtained by Alexander,[12] from places where there is no net runoff to or away from the sampling locations, may also be used for this purpose, but suitable sites for obtaining soil data are few and small in area.

No real relationship exists between Sr^{90} activity levels and total gross beta activity and dissolved gross beta activity levels, as shown in Fig. 2 and 3, respectively. The inset plots, which include only lake activity values, seem to show some general correlation—that is, Sr^{90} activity increases as the total and dissolved beta activities increase. It is not surprising to find this relationship, for lakes retain most of their activity. River systems are dynamic, and activity found in one location on one day will have moved elsewhere with the passage of time.

In the water supply field, runoff is of primary interest. Because runoff constitutes the source of the bulk of usable waters, it is important to know how much Sr^{90} contained in precipitation finds its way into water courses and water supplies. Data on precipitation levels are available for specific areas, as shown in Table 2. A comparison of these data with strontium levels in streams provides accurate data

TABLE 3

Activity of Sr^{90} in Coast Guard and Private Cistern Waters

Cistern Waters	Date*	No. of Observations	Activity—$\mu\mu c/l$		
			Mean	Median	Range
Coast Guard	IV 1958	2	4.0	4.0	2.76–5.17
	I 1959	12	3.7	3.7	0.9–7.3
	II 1959	10	3.2	3.0	0.2–8.5
	III 1959	9	1.1	0.4	0.2–3.5
Private	Jan. 1959	7	4.9	4.9	3.4–6.0
	Feb. 1959	8	6.4	5.5	3.5–14.6
	Apr.–Jun. 1959		11.3		
	Jul.–Sep. 1959		1.0		
	Oct. 1959		5.9		

* Roman numerals represent quarters of the year: I, first quarter; II, second quarter; III, third quarter; and IV, fourth quarter.

TABLE 4

Average Gross Beta Radioactivity and Sr^{90} Radioactivity—Data From National Water Quality Network (1958–1959)

Drainage Basin Station	Oct.–Dec. 1958			Jan.–Mar. 1959			Apr.–Jun. 1959			Jul.–Sep. 1959		
	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$
	Dissolved	Total		Dissolved	Total		Dissolved	Total		Dissolved	Total	
Great Lakes												
Duluth, Minn.	8	9		13	16	0.7	14	17	0.1	3	4	0.2
Gary, Ind.	16	18		14	21	0.7	27	44	1.0	11	16	0.4
Detroit, Mich.	13	16		31	31	0.5	37	37	0.4	8	13	0.6
Buffalo, N.Y.	20	24		16	21	1.1	25	32	1.3	14	17	0.8
*N. Atlantic Coastal Area**												
Lowell, Mass.	42	54		34	128	1.6	27	55	2.1	15	21	1.2
Poughkeepsie, N.Y.	32	56		62	112	4.5	46	71	1.1	7	18	1.0
Hagerstown, Md.	27	32		25	45	1.4	26	40	1.3	10	13	0.7
Great Falls, Md.	29	36		23	43	2.4	39	52	1.0	9	14	0.8
Philadelphia, Pa.	23	33		44	86	0.8	72	93	1.1	13	15	0.6
Easton, Pa.							43	56	2.0			
Northfield, Conn.							5	7		7	12	1.9
Savannah River												
N. Augusta, Ga.	43	46		14	39	0.6	19	49	2.8	8	14	0.3
Savannah, Ga.	34	42		19	42	1.4	24	53	1.9	22	29	0.7
Tennessee River												
Chattanooga, Tenn.	25	27		27	46	4.7	57	88	4.8	33	35	3.8
Rio Grande River												
El Paso, Tex.	35	46		40	138	0.7	67	123	1.1	32	98	0.3
Laredo, Tex.	45	166	0.3	31	40	0.3	90	176	1.1	17	213	0.2

* Lowell, on the Merrimack River; Poughkeepsie, on the Hudson River; Hagerstown, on the Potomac River; Great Falls, on the Potomac River; Philadelphia and Easton, on the Delaware River; and Northfield, on the Connecticut River.

TABLE 4—*Average Gross Beta Activity and Sr^{90} Radioactivity (contd.)*

Drainage Basin Station	Oct.–Dec. 1958			Jan.–Mar. 1959			Apr.–Jun. 1959			Jul.–Sep. 1959		
	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$
	Dissolved	Total		Dissolved	Total		Dissolved	Total		Dissolved	Total	
Colorado River												
Loma, Colo.	62	103		87	111	2.9	38	101	0.7	34	54	0.3
Boulder City, Nev.	26	28		20	59	1.8	70	82	1.2	21	23	0.9
Parker Dam, Calif.	27	28		36	77	0.9	141	226	2.7	21	24	0.6
Yuma, Ariz.	35	45		47	56	0.7	93	177	1.6	11	17	0.8
Arkansas River												
Coolidge, Kan.	67	88		77	112	2.4	166	291	1.7	101	176	1.4
Ponca City, Okla.	53	66		59	130	1.6	175	253	2.4	26	57	0.5
Ft. Smith, Ark.										42	185	2.1
Pendleton Ferry, Ark.				50	190	0.3	120	350	2.2	26	106	0.3
Columbia River												
Wenatchee, Wash.	12	14		58	71	0.6	30	38	0.8	6	8	0.5
Pasco, Wash.	681	750		587	640	1.4	301	363	1.2	289	325	1.0
Bonneville, Ore.	207	228	0.9	238	299	0.9	141	187	1.1	181	211	0.5
Clatskanie, Ore.	103	158		143	211	0.7	134	189	1.2	135	156	0.5
Snake River												
Weiser, Idaho	14	16		24	49	0.4	57	76	0.4			
Wawawai, Wash.	20	30		30	51	0.5	28	63	0.9	12	16	0.4
Alsea River												
Alsea, Ore.				14	20	0	20	26	0.2	9	13	0.2
Red River												
Denison, Tex.	24	29		56	70	2.0	139	154	2.3	16	23	1.0
Index, Ark.							67	72		26	54	0.6
Alexandria, La.	28	39		44	116		85	157	2.5	14	20	0.4

TABLE 4—*Average Gross Beta Activity and Sr^{90} Radioactivity (contd.)*

Drainage Basin Station	Oct.–Dec. 1958			Jan.–Mar. 1959			Apr.–Jun. 1959			Jul.–Sep. 1959		
	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$	Beta Activity $\mu\mu c/l$		Sr^{90} $\mu\mu c/l$
	Dissolved	Total		Dissolved	Total		Dissolved	Total		Dissolved	Total	
Ohio River												
E. Liverpool, Ohio	90	99		36	66	0.9	30	55	2.1	9	10	1.2
Huntington, W.Va.	26	32		64	141	0.8	19	58	1.1	22	30	1.0
Cincinnati, Ohio	36	45		23	66	0.6	26	61	0.9	12	17	0.9
Evansville, Ind.	32	34		29	87	1.8	22	53	1.6	15	19	2.0
Cairo, Ill.	25	30		40	97	1.1	57	84	2.9	15	17	1.2
Missouri River												
Sidney, Mont.	23	36		66	137	0.8	64	164	1.9	12	66	0.7
Williston, N.D.	40	86	0.4	29	41	1.6	39	152	1.4	8	48	0.5
Bismarck, N.D.	20	27		32	45	0.4	66	90	1.5	19	22	0.8
Yankton, S.D.	26	31		31	35	0.8	59	91	2.2	27	30	0.4
Omaha, Neb.	32	49		37	74	0.5	61	194	2.1	19	39	1.1
St. Joseph, Mo.	31	43		60	165	0.7	55	518	1.3	24	120	0.6
Kansas City, Kan.	30	69		54	189	0.8	72	232	1.7	22	111	0.3
St. Louis, Mo.	42	106	0.9	90	180	0.7	51	270	0.6	13	70	0.5
Mississippi River												
Red Wing, Minn.	34	46		35	38	1.3†	74	109	1.6	17	21	0.5
Dubuque, Iowa	17	22	1.0	37	47	1.1	150	192	1.5	14	16	1.6
Burlington, Iowa	27	41		63	146	1.1	267	446	2.1	20	48	1.1
E. St. Louis, Ill.	35	50		84	181	1.4	84	225	3.4	9	20	1.2
Cape Girardeau, Mo.	28	64	1.0	53	143	1.2	142	342	1.6	30	68	1.2
West Memphis, Ark.	33	50		76	149	0.9	73	178	2.1	10	23	1.3
Vicksburg, Miss.	21	42		98	169	1.0	39	137	1.3			
Delta, La.							76	153		15	38	1.3
New Orleans, La.	37	46		28	97	1.2	50	134	0.8	14	21	1.0

TABLE 5

Activity of Sr^{90} in Rivers

Source of Activity	Date	No. of Samples	Activity $\mu\mu c/l$	
			Avg	Range
Animas River	1958	7	0.8	0.4–1.1
Delaware River area	Mar. 1959	7	1.2	0.4–2.0
	Apr. 1959	1	1.3	
	May 1959	1	0.5	
	Jun. 1959	1	1.2	
	Jul. 1959	2	1.0	1.0–1.1
Mohawk River, upstream of KAPL*	Nov. 1958	4	1.7	0.5–5.4

* Knolls Atomic Power Laboratory, Schenectady, N.Y.

on the retention of strontium on land areas, and also makes possible estimates of the potential hazard to surface drinking water supplies, regardless of their source: lakes, reservoirs, impoundments, or rivers and streams.

If the Sr^{90} data given in Table 2 are averaged, and if it is assumed that this average value is the strontium deposition or loading over the continental United States, Sr^{90} deposited during the last quarter of 1958 is approximately 96 c/day. If the data shown for the first quarter of 1959 are included, the Sr^{90} loading amounts to approximately 236 c/day. These values may be compared with an estimate of Sr^{90} runoff ($0.9\ \mu\mu c/l$ * $\times 1.2 \times 10^{12}$ gpd runoff † $\times 3.785$ liters/gal $\times 10^{-12}$ c/$\mu\mu$c) of 4.1 c/day for the first quarter of 1959.

The total gross beta fallout activity contributed by precipitation, calculated from data available from USPHS[13] and the National Radiation Surveillance Network (October 1958–June 1959),[14] amounts to:

$$1{,}470\ \mu\mu c/l \times 4.3 \times 10^{12}\ \text{gpd} \times 3.785\ \text{liters/gal} \times 10^{-12}\ \text{c}/\mu\mu\text{c} = 23{,}900\ \text{c/day}.$$

* From Fig. 1.
† From Ref. 13.

From the National Water Quality Network data on total gross beta activity,[15] the amount of fallout activity reaching the streams amounts to:

$$90\ \mu\mu c/l \times 1.2 \times 10^{12}\ \text{gpd} \times 3.785\ \text{liters/gal} \times 10^{-12}\ \text{c}/\mu\mu\text{c} = 408\ \text{c/day}.$$

The total gross beta activity retained on land and vegetation or lost through decay amounts to:

$$23{,}900\ \text{c/day} - 408\ \text{c/day} = 23{,}500\ \text{c/day}$$

or 98.4 per cent.

The values given above are average estimates for the country as a whole. Inasmuch as extensive data are lacking for many geographic areas, the authors selected the area around Cincinnati, where some data on Sr^{90} levels in rainfall are available, and related these levels to the Sr^{90} levels in the Ohio River. Current flow data were obtained from the Ohio River Valley Water Sanitation Commission (Orsanco). The river flows at stations nearest the corresponding National Water Quality Network stations are shown in Table 6.

With the data from Table 6 and the Sr^{90} levels given in Table 4, it is possible to calculate the curies of strontium

TABLE 6

Quarterly Ohio River Flows, 1958–1959

Station*	Average Flow†—*cfs*			
	IV	I	II	III
E. Liverpool, Ohio	20,700	72,300	39,900	7,000
Huntington, W.Va.	32,100	140,000	82,300	16,700
Cincinnati, Ohio	36,500	176,300	98,800	18,000
Evansville, Ind.	52,600	231,000	128,000	33,200
Cairo, Ill.	113,000	417,000	239,000	83,900

* The flows at some stations were computed on the basis of proportionate drainage areas, from data in provisional records of various cities: at E. Liverpool, from records of Sewickley, Pa.; at Evansville, from records of Louisville, Ky., and Metropolis, Ill.; and at Cairo, from records of Metropolis, Ill.

† Roman numerals designate the quarter of the year: fourth quarter of 1958; first to third quarters of 1959.

passing each station during each quarter of the year. These values are shown in Table 7. When the values are divided by the drainage areas,[16] the "unloading" or runoff activity may be calculated (Table 8). By a comparison of these data with precipitation rates for corresponding periods, it is possible to estimate the overall degree of Sr^{90} removal by natural agents taking place in each of the drainage basins (Table 9).

Precipitation data and Sr^{90} levels were reported for Pittsburgh and Louisville.[5, 6] Previously mentioned data on total strontium levels obtained in Cincinnati were extrapolated to estimate Sr^{90} levels in precipitation for the Ohio River Valley stations listed in Tables 6, 7, and 8. The Pittsburgh rainfall and Sr^{90} values were adjusted in accordance with the rainfall at E. Liverpool and Huntington; the Pittsburgh and Louisville values, with the

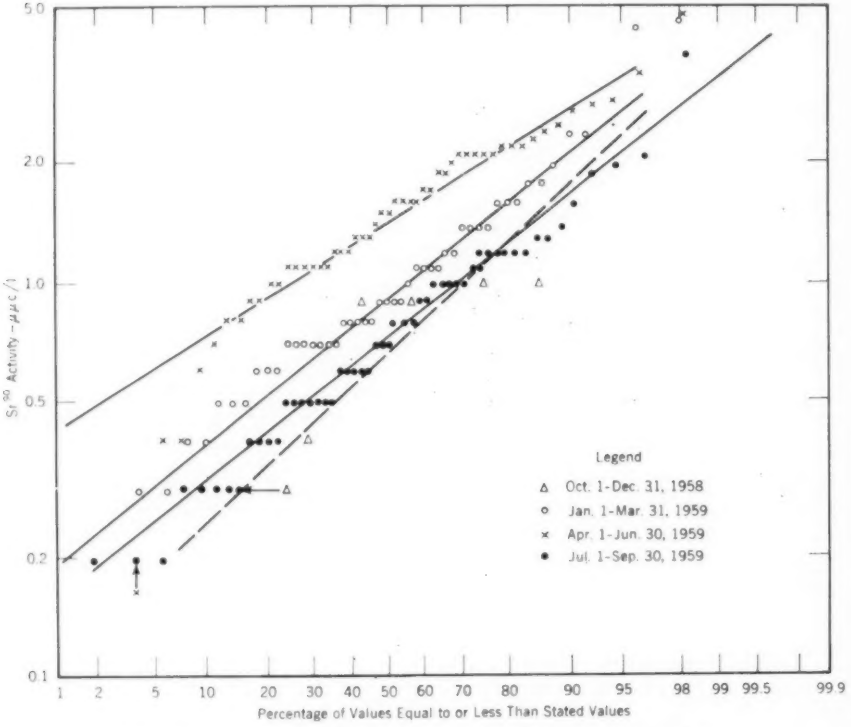

Fig. 1. Quarterly Sr^{90} Activity: Oct. 1, 1958–Sep. 30, 1959

The geometric mean of Sr^{90} activity (excluding the first series of only six samples) was 0.91 μμc/l for Jan. 1–Mar. 31, 1959; 1.42 μμc/l for Apr. 1–Jun. 30, 1959; and 0.72 μμc/l for Jul. 1–Sep. 30, 1959.

TABLE 7

Activity of Sr^{90} in the Ohio River

Station	Activity*—*curies*				
	IV†	I	II	III	Overall Total
E. Liverpool, Ohio	3.3	14.3	18.6	1.9	38.1
Huntington, W.Va.	5.0	24.6	20.1	3.8	53.5
Cincinnati, Ohio	5.8	23.3	19.7	3.6	52.4
Evansville, Ind.	8.3	91.5	45.5	15.0	160.3
Cairo, Ill.	17.8	101.0	154.0	22.6	295.4

* Roman numerals designate the quarter of the year: fourth quarter of 1958; first to third quarters of 1959.
† Mean value of 0.7 $\mu\mu c/l$ Sr^{90} assumed to apply to all stations.

rainfall at Cincinnati; and the Louisville values, with the rainfall at Evansville and Cairo. The results obtained for the first quarter of 1959 are shown in Table 9.

From these data, the amount of Sr^{90} deposited per day during the first quarter of 1959 was found to be 15.3 c/day. The 1.2 c/day runoff in the Ohio River Valley may be compared to the nationwide Sr^{90} runoff of 4.1 c/day for the same period. These values may be compared to the Ohio River Valley deposition (loading) and runoff (unloading) values of 45,400 c/day and 112 c/day of total gross beta activity, respectively, and to the nationwide deposition and runoff values of 23,900 c/day and 408 c/day of total gross beta activity, respectively.

The high Sr^{90} levels measured at Chattanooga, Tenn. (4.7, 4.8, and 3.8 $\mu\mu c/l$ for the first three quarters of 1959) may be attributed in part to the release of mixed fission products from the Oak Ridge National Laboratory. Morgan[17] has provided data (Table 10) on the amounts of Sr^{90} discharged into the Clinch River and Tennessee River systems during the period 1954–1958. For an average flow of 26,500 cfs at Chattanooga (1959 water year), the reported discharges were converted to the average concentration levels shown in Table 10. It will be seen that these values are of the same order of magnitude as those found in the Tennessee River at Chattanooga during 1959. Because current contributions of Sr^{90} fallout are on the order of 1 $\mu\mu c/l$ (taken from Fig. 1)—levels in previous years were probably lower than 1 $\mu\mu c/l$—it may be assumed that the Oak Ridge National Laboratory Operations have increased the Sr^{90} content of the Tennessee River by an amount in the approximate range of 3–5 $\mu\mu c/l$.

Summary and Conclusions

Levels of Sr^{90} activity were determined for the major surface waters of the United States. From these values, it was calculated that the average runoff of Sr^{90} in these waters amounts to 4 c/day, corresponding to 0.5 mc/sq mi/yr, or 190 $\mu\mu c$/sq m/yr. The total gross fallout contribution was calculated as 23,900 c/day, of which 408 c/day is found in runoff. Calculations also showed that at Chattanooga the major source of Sr^{90} was not fallout but Oak Ridge National Laboratory operations. This condition is not found at the Hanford or Savannah River op-

TABLE 8

Runoff Activity of Sr^{90}

Station	Drainage Area *sq mi*	Runoff*—$\mu\mu c$/*sq m*				
		IV	I	II	III	Overall Total
E. Liverpool, Ohio	23,500	54	235	306	31	626
Huntington, W.Va.	53,980	36	176	144	27	383
Cincinnati, Ohio	71,150	31	126	107	20	284
Evansville, Ind.	107,000	30	330	164	54	578
Cairo, Ill.	203,100	34	192	293	43	562

* Roman numerals designate the quarter of the year: fourth quarter of 1958; first to third quarters of 1959.

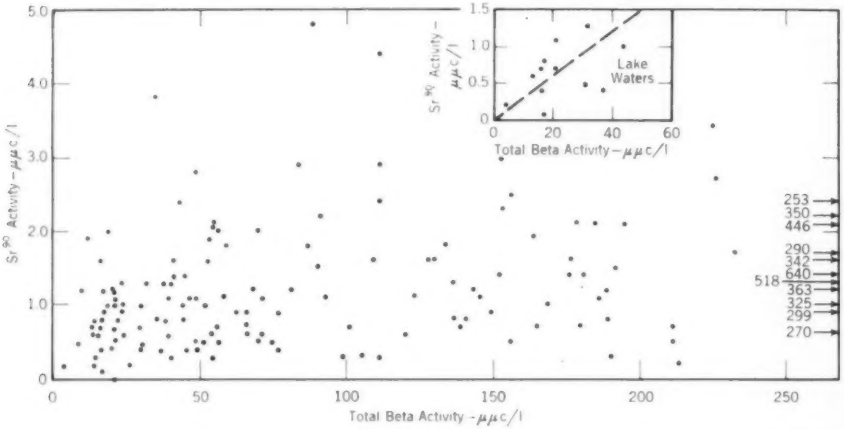

Fig. 2. Relationship Between Sr^{90} and Total Beta Activities in Lake and River Waters

The inset plots of lake water activity show a general correlation between Sr^{90} and total beta activities. The other plots, however, of river water, show that no real relationship exists between the two types of activity.

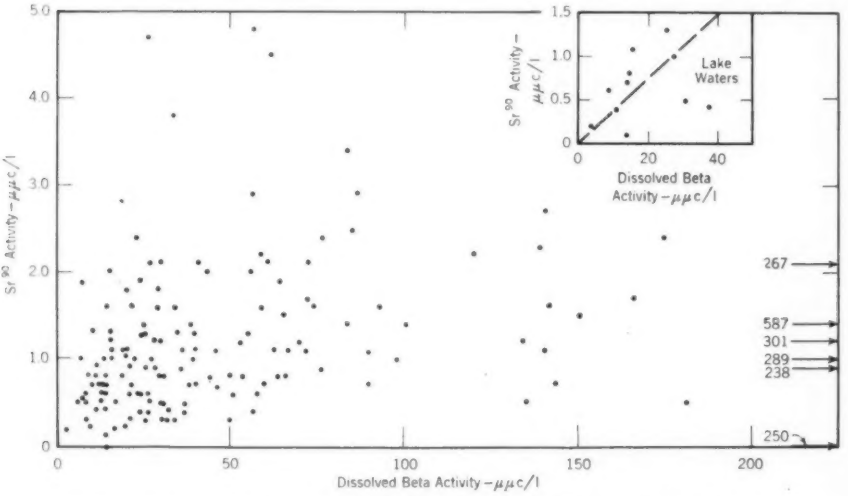

Fig. 3. Relationship Between Sr^{90} and Dissolved Beta Activities in Lake and River Waters

The relationship between the two types of activity is similar to that shown in Fig. 2—a general correlation between Sr^{90} and dissolved beta activities in lake water, but no real relationship between the two activities in river water.

erations. Estimated rates of Sr^{90} runoff, from 1958 and 1959 flow data in the Ohio River Valley, showed somewhat higher levels than the average value of 190 $\mu\mu c$/sq m/yr.

The current maximum permissible concentration level of Sr^{90} in drinking water for an uncontrolled area is 100 $\mu\mu c$/l.[18] One-third of this concentration has been suggested as the *average* concentration applicable to the entire population. The contribution to general Sr^{90} intake from water alone is quite small, certainly less than 5 per cent of the maximum permissible concentration. Food, however, not water, is the major vehicle of Sr^{90} intake. On the average, water may be responsible for 10 per cent of ingested Sr^{90}. In Chattanooga or in places where cisterns are used as a source of supply, the Sr^{90} from water is nearly 35–50 per cent of the total intake.

Acknowledgments

The gross beta activity results are from the National Water Quality Network, Water Pollution Control Division. The authors express appreciation to the many individuals who participated in the network. Special thanks are given to Stanley Baker, Elaine Goins, and Anna Lett for the beta analysis and Sr^{90}-sample compositing; to Jasper Kearney and George Frishkorn, for the Sr^{90} analyses; and to Byron Branson, for instrumental analysis. Acknowledgment is made to the Program Operations Branch, Division of Radiological Health, for the use of National Surveillance Network data on rainfall and rainout; to the Ohio River Valley Water Sanitation Commission, for provisional flow information on the Ohio River; and to the Hydraulic Data Section, TVA, for providing provisional data on flow rates at Chattanooga, Tenn.

TABLE 9

Strontium-90 in Precipitation and Runoff—Ohio River Valley (First Quarter, 1959)

Station	Precipitation (Loading) $\mu\mu c$/sq m	Runoff (Unloading) $\mu\mu c$/sq m	Overall Retention %
E. Liverpool, Ohio	2,200	235	89.3
Huntington, W.Va.	1,980	176	91.5
Cincinnati, Ohio	3,230	126	96.1
Evansville, Ind.	2,700	330	87.8
Cairo, Ill.	2,980	192	93.6

TABLE 10

*Activity Levels of Sr^{90} at Chattanooga, Tenn.**

Year†	Activity Released at ORNL‡ curies	Activity at Chattanooga curies	
		Calculated	Measured
1954	123	5.2	
1955	97	4.1	
1956	76	3.2	
1957	92	3.9	
1958	78	3.3	
1959 I			4.7
II			4.8
III			3.8

* Assumed flow of 26,500 cfs.
† Roman numerals designate the quarter of the year.
‡ Oak Ridge National Laboratory, Oak Ridge, Tenn.

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Natural Radioactivity in Illinois Water Resources

Thurston E. Larson and Richard L. Weatherford

A contribution to the Journal by Thurston E. Larson, Head, Chemistry Sec., and Richard L. Weatherford, Asst. Chemist, both of the State Water Survey Div., Urbana, Ill.

VARIOUS isotopes have different levels of significance or limiting parameters of health hazard. Methods of radioactivity measurement vary, frequently from one laboratory to another, even to the extent that the measurements are often only roughly comparable. All radioactivity measurements at the Illinois State Water Survey, Urbana, Ill., made since May 1957 have been of samples of well waters, streams, and rivers. These measurements have been limited to gross alpha and beta activities by proportional counting of the nonvolatile residue remaining after evaporation of the water carrier. Such residues do not contain tritium, which will, therefore, not be discussed and which, furthermore, has a very low level of energy with a half-life of 12 years. It is of interest, however, as shown by Libby,[1] that the beta activity of tritium in the Mississippi River was 5–20 $\mu\mu$c/l; in Lake Michigan, 5 $\mu\mu$c/l; and in rainfall in the Midwest, approximately 20 $\mu\mu$c/l.

For low levels of activity, an error of approximately 50 per cent was estimated with the levels of confidence shown in Table 1. Therefore, any appreciable confidence in results cannot be extended to activities of less than about 3 $\mu\mu$c/l (relative to 20-min counting in duplicate for 250-ml samples). For 50 per cent confidence at an activity of 3 $\mu\mu$c/l, a 2-hr counting period would be required. Favorable limitations of the counting procedures are further degraded by the absence of specific information on the self-absorption that results from the deposition of neutral mineral salts from the samples containing nuclides responsible for radioactivity.

The physiologic significance of gross activity and specific radioactive isotopes, and the optimum and standard procedures for the determination of gross and specific activities, will not be discussed. Consideration will be given to: (1) the radioactivity of ground waters, which have been used as public supplies for more than four generations and which, for all practical purposes, contain only those isotopes of long half-lives; (2) excerpts from, and interpretations of, data on Ra^{226} by Lucas and Ilcewicz [2] of Argonne National Laboratories, Lemont, Ill.; and (3) data on gross activity of surface waters, with particular emphasis on measurements of gross dissolved beta radioactivity, with reference to the natural activity of Illinois water resources.

Ground Water

Since Jun. 1, 1957, about 300 well water samples have been examined for gross alpha and beta activities. When the data were assembled, waters known

to be from the St. Peter or Galesville sandstones and three samples from Galena-Platteville dolomite, all from the Cambrian-Ordovician period, were grouped together. Then the waters from the Silurian and Devonian limestones were grouped together, as were the waters from the unconsolidated formations in the glacial deposits and outwash or alluvium deposits. The remaining eleven samples represented waters from the sandstones and dolomites of the Mississippian and Pennsylvanian periods.

In each group of waters, the activities were ranked in order of the magnitude of beta activity, and the frequency of occurrence of activity at concentrations above any particular level was calculated. The beta activity was used because its magnitude was greater, in almost every instance, than the alpha activity, which, with relatively few exceptions, was negligible. The frequency of occurrence of various levels of activity in ground waters is shown in Fig. 1.

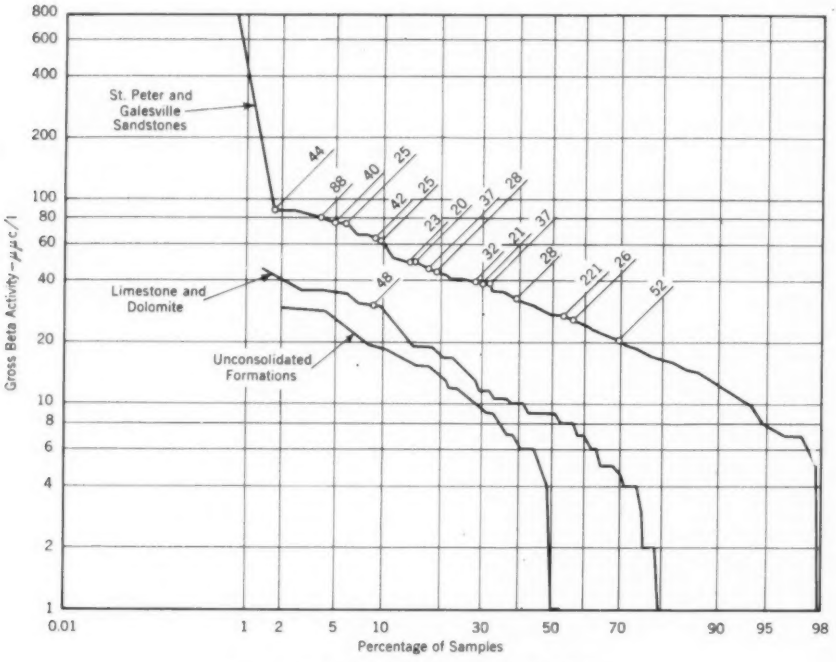

Fig. 1. Gross Activity of Ground Water

The numbers on the curves are the alpha activities (in micromicrocuries per liter) of eighteen samples with alpha activities exceeding 20 μμc/l. A total of 49 samples from the unconsolidated formations was tested; 73 from the limestone and dolomite; and 126 from the St. Peter and Galesville sandstones.

Beginning with the top or unconsolidated formations above the bedrock, the level of activity for 49 samples was 1 μμc/l or less for 50 per cent of the samples; none of the samples showed an

activity in excess of 30 μμc/l. About 25 per cent of the samples exceeded an activity of 10 μμc/l. The alpha activity did not exceed 8 μμc/l in any sample, and exceeded 5 μμc/l in only one. These data represent the normal range of activity for the waters from the glacial deposits, alluvium, and outwash along flowing streams. Although the four highest levels were from Illinoisan and Kansan glacial deposits, five other samples from the same sources had essentially no activity.

The number of samples from the Mississippian and Pennsylvanian periods were too few to be statistically significant, but the range of activities lay within the range of activity levels in the dolomites. These formations exist between the unconsolidated deposits and the Silurian or Devonian formations over the greater part of the state, but they are not particularly significant as a source of public water supplies.

The Devonian and Silurian dolomites and limestones are present below the coal measures and are important sources of public water supplies in the northern part of the state in the Rock Island area and in a strip extending from Iroquois County to the Wisconsin border. Of 73 samples, 20 per cent were found to have essentially no activity. Forty per cent had an activity of 10 μμc/l or more, and none exceeded 45 μμc/l. The ten highest levels of activity were from the Silurian dolomite, but because all except two of the thirteen lowest levels were also from the Silurian samples, there appears to be no distinguishing feature between waters of the Silurian and Devonian formations. The six known Devonian samples had a beta activity of 0–18 μμc/l. The alpha activities exceeded 10 μμc/l only three times, once to a level of 48 μμc/l.

With regard to the greater number of the samples, these formations lie directly below the unconsolidated deposits. Therefore, it is reasonable to expect a hydrologic interrelationship between the two, accounting for the general similarity in the lower range of levels of activity.

For the data on waters of the Cambrian-Ordovician period from the St. Peter and Galesville sandstones, 126 samples showed a median beta activity of 28 μμc/l. Of these samples, only two showed no activity and one an activity of more than 86 μμc/l. There is only a slight difference between the activities of waters from the St. Peter and Galesville sandstones, as both waters are represented among those with the ten highest levels and the ten lowest levels of activity.

TABLE 1

Levels of Confidence for Low Levels of Radioactivity

Radioactivity μμc/l	Level of Confidence %
15	95
9	83
6	62
3	30

At locations west of the Illinois River, there appears to be a high proportion of these waters with higher levels of activity. St. Peter and Galesville waters are also usually characterized by the presence of significant alpha activity. The activities of seventeen samples with greater than 20 μμc/l alpha activity are plotted in Fig. 1. Only 33 of the 126 samples showed less than 5 μμc/l alpha activity.

Several samples from one particular well gave considerable difficulty in duplicating results—perhaps, to some extent, owing to a total dissolved mineral content of 1,266 ppm. It did appear, however, that considerable alpha

activity was present and, on recounts, the samples showed an increase in this activity between successive intervals of several months' storage. From these data it appears that at least 90 per cent of the samples showed a beta activity in the range of 10–90 $\mu\mu c/l$.

Radium-226

Lucas and Ilcewicz [2] reported on Ra^{226} present in samples collected

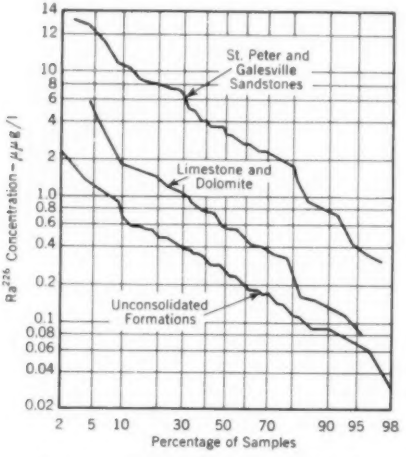

Fig. 2. Radium-226 in Municipal Well Waters

The median concentration of Ra^{226} for all wells that derive all or part of their water from the Cambrian-Ordovician and Precambrian periods was 3 $\mu\mu g/l$.

from all communities in 51 randomly selected counties of the 102 counties in the state. Identification of sources of the well water supplies was made by the Illinois Water Survey from analyses of separate samples collected at each location. These data are shown in Fig. 2.

The average Ra^{226} content was 0.04 $\mu\mu g/l$ for 28 surface water supplies, with a range of 0.00–0.15 $\mu\mu g/l$, which is in accordance with an average of 0.03$\mu\mu g/l$ found by Hursh [2] for 35 major cities in the United States. The waters from the unconsolidated formations had a median concentration of 0.25 $\mu\mu g/l$. Several of the very low values were from wells in the alluvium or outwash deposits, and the presence of nitrates indicated that these waters were from recent recharges. Waters from the Devonian and Silurian limestones showed a median concentration of 0.6 $\mu\mu g/l$. The highest value represents water from a well located very near a St. Peter sandstone well that does not have the upper limestone formation cased off. Therefore, free movement of water between the two wells is known to occur. For limestone wells located in areas of sink holes, very low values were recorded; the waters probably were from recent recharges.

The Pennsylvanian sandstone waters were too few to be statistically important, but five of the six values for wells south of Alton and Lawrenceville had relatively high values. For the deep sandstone or the St. Peter and Galesville waters, some values were obtained from wells entering the Mt. Simon sandstone of the Precambrian period. The six highest values, however, represent waters from the St. Peter sandstone. This fact is significant, but it was noted that six of the thirteen lowest values were also from the St. Peter sandstone. No Mt. Simon water sample exceeded a Ra^{226} content of 5 $\mu\mu g/l$.

The median concentration of Ra^{226} for all wells that derive all or part of their water from the Cambrian-Ordovician and Precambrian periods was 3 $\mu\mu g/l$. Although there is a similarity in the relative range of Ra^{226} activity as compared with the gross beta activity shown in Fig. 1, detailed

examination indicated no direct correlation between the two. Lucas[4] recently summarized data on Illinois populations using public supplies with various levels of Ra^{226} content (Table 2).

Surface Water

For the past 2½ years, USGS has cooperated with the Illinois Water Survey at jointly operated gaging stations in the collection of samples, once a month, from eighteen rivers in Illinois. The number and frequency of samples are not yet sufficient statistically to provide more than a general indication of the range of activities. Additional samples are being obtained from two sampling points at Crab Orchard Lake, from the Ohio River at Cairo, and from the Mississippi River at East St. Louis. Data are also available from biweekly samples taken since February 1958 from the Illinois River at the intake to the recharge pits at Peoria. These are taken most frequently and provide the greatest number of samples from a single location. Each of the surface water samples is examined for gross alpha and beta activities in the soluble form and also, by separate determinations, for activity in the suspended matter.

TABLE 2

Radium-226 Concentrations in Water Consumed by Illinois Populations

Maximum Concentration $\mu\mu g/l$	Number of Cities	Population†
0–0.99*	134	1,068,610
1.0–3.9	42	213,532
4.0–9.9	34	310,588
10–37	19	30,261

* Includes data on all types of water source, in addition to deep sandstone.
† 1950 census.

The data for the Illinois River at Peoria are shown in Fig. 3. In ranked order of magnitude of total activity, the median level was 40 $\mu\mu c/l$, with 90 per cent of the samples in the range of 13–250 $\mu\mu c/l$ and 20 per cent containing more than 100 $\mu\mu c/l$. It is of interest to note that the total activity is in no way related to the turbidity, for which corresponding values are also plotted in Fig. 3. It is perhaps also significant that the turbidity at this sampling point is rarely greater than 100 ppm. Direct treatment of suspended activity and suspended solids showed no consistent relationship to each other.

In general, high levels of total activity are associated with intense rainfall and streamflow (Fig. 4). There were two periods of dissolved activity (more than 100 $\mu\mu c/l$) when this activity constituted the major portion of the total activity: in August 1958, for a period of about 5 weeks, and in March 1959, for a period of 2 weeks. After the first period, the high levels continued, even for lesser flows, for about 2 months. After the second period, the high levels continued for approximately 6 weeks.

Because reservoirs are designed to fill and hold runoff during periods of intense streamflow, such prolonged flow periods with high levels of dissolved activity could cause alarming conditions. The suspended activity would cause less difficulty, because regular clarification practices at treatment plants are designed to remove suspended matter.

Incidental to the collection of samples from the Illinois River, data on dissolved activity were also obtained in samples collected from a well located about 90 ft from the recharge pits. Before June 1958, the dissolved activity for these samples was normally

0–25 $\mu\mu c/l$. Little change was noted during the summer of 1958, when recharging was not attempted; but, in February 1959, this activity increased to 30–60 $\mu\mu c/l$ during the period through April and then returned to its previous level. These generalized data indicate incomplete removal of the activity by the soil during this recharge period when high levels of dissolved activity occurred in the river water. But the objective here is to consider natural activity; therefore, low levels of dissolved activity will be discussed in an attempt to evaluate the data to indicate the natural activity of the water.

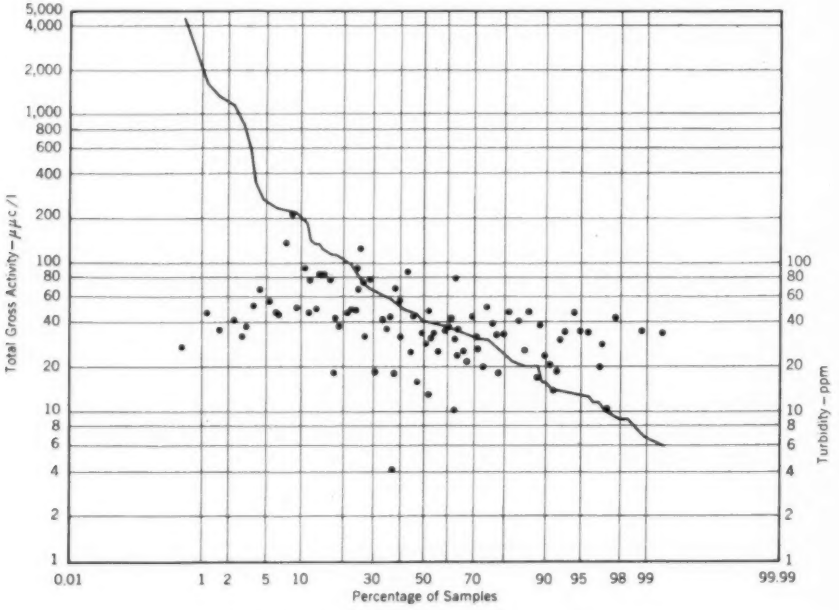

Fig. 3. Data on Illinois River at Peoria

The curve refers to the total gross activity; the circles, to turbidity. The data were collected during Jun. 28, 1957–Sep. 25, 1959.

Dissolved Activity

Because the high levels of activity are associated with intense streamflow and rainfall, such excess activity may be recognized as the result of direct scrubbing of the atmosphere (rainout) and as the result of the washing of man-made structures, topsoil, and foliage by rainfall. Under current conditions, any dilution effect that rainfall may have is far outweighed by its pickup of activity before entering the stream. If this relationship continues through medium flow periods to minimum flow periods, the natural activity should be represented as that recorded at minimum flow periods after a long dry period. Accordingly, minimum activities have been observed in September and October, when the streamflow is at its natural minimum.

When the average daily dissolved activity passing the sampling point at the

time of collection of each sample was calculated, it was noted that the minimum daily discharge of activity occurred during periods of less intense flow. The four lowest daily values were 91,000 μc, 49,000 μc, 104,000 μc, and 64,000 μc.

In the watershed area, 58 mil gal of ground water was pumped daily for municipal and industrial use from the deep sandstones (Cambrian-Ordovician and Precambrian periods). If it is assumed that percentages of this pumpage have beta activity indicated by the probability data in Fig. 1, the total dissolved beta activity contributed daily from this source to the streamflow of the Illinois River at Peoria is about 6,830 μc. Likewise, the pumpage of 64 mgd from limestone contributes 1,400 μc/day, and the pumpage of 21 mgd from unconsolidated formations contributes 530 μc/day. Thus, the ground water pumpage of 143 mgd has an average activity of 16.3 μμc/l and contributes 8,760 μc/day, with a contribution to the streamflow of 218 cfs. It is probable that about 2 cfs is also being contributed by exposure of St. Peter sandstone to the river bottom from Ottawa to LaSalle; nearly 140 μc/day comes from this source. Thus, there is a total ground water contribution of about 8,900 μc/day.

There are, of course, other ground water contributions from alluvial deposits along the streams of the watershed, but it is difficult to assume an activity for such waters. These waters, in large part, enter the formations dur-

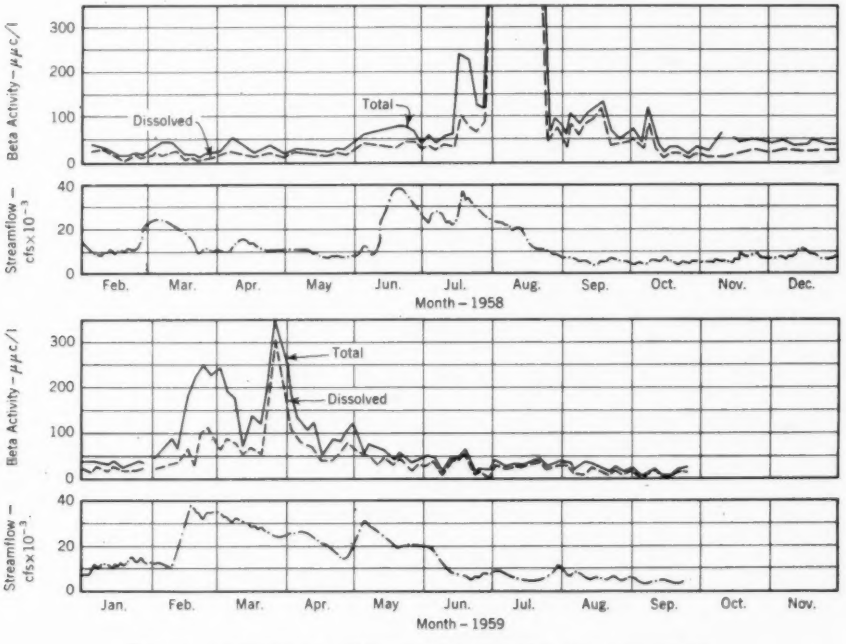

Fig. 4. Relationship Between Beta Activity and Streamflow

In general, the greater the streamflow, the greater the total activity.

ing intense streamflow (and high levels of activity) by infiltration, but it is reported[5,7] that the soils absorb some of the radioactive nuclides and serve as scavengers. This condition will vary to the extent that the nuclides remain fixed or subject to ion-exchange equilibria conditions.

rainfall and runoff, would be 24,500 $\mu\mu c$/day, corresponding to a concentration of 3 $\mu\mu c$/l in the combined water flow of 3,420 cfs. Thus, the activity of the runoff could be estimated by:

$$A = \frac{B \times \text{cfs} \times 2.44 - 24{,}500}{2.44\ (\text{cfs} - C + D)}$$

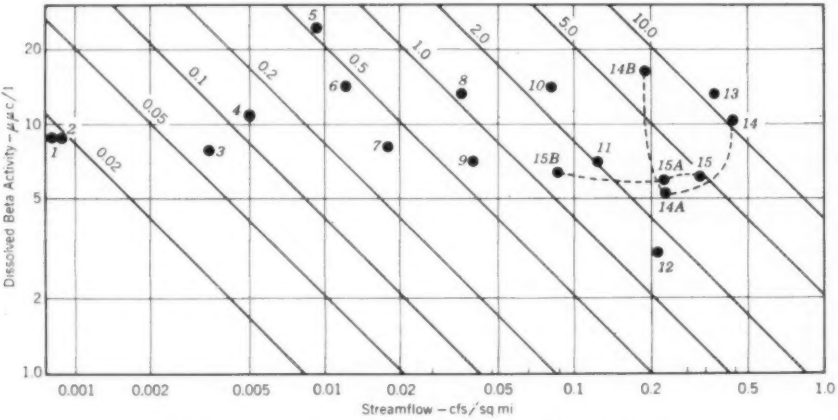

Fig. 5. Activity and Streamflow at Sampling Points

The numbered circles indicate the streams sampled (the names of cities on stream where samples were collected are given in parentheses): 1, Cache; 2, Skillet Fork (Wayne City); 3, Kaskaskia (Shelbyville); 4, La Moine (Colmar); 5, Big Muddy (Murphysboro); 6, Little Wabash (Carmi); 7, Vermillion (Pontiac); 8, Fox (Dayton); 9, Kaskaskia (New Athens); 10, Mississippi River (E. St. Louis); 11, Fox (Algonquin); 12, Apple (Hanover); 13, Ohio River (Cairo); 14, Illinois River (Peoria, Sep. 24, 1959); 14A, ground water plus Lake Michigan contribution; 14B, runoff contribution; 15, Illinois River (Peoria, Sep. 10, 1959); 15A, ground water plus Lake Michigan contribution; and 15B, runoff contribution. The values on the curves represent minimum loads in microcuries per day per square mile. The tick marks on the abscissa refer to those samples assumed to have a beta activity of approximately 1 $\mu\mu c$/l.

The natural activity of Lake Michigan water has been reported to be approximately 2 $\mu\mu c$/l. Therefore, if it is assumed that a flow of 1,700 cfs is used by Chicago for its water supply and 1,500 cfs is diverted, the total contribution of activity, including the known ground water contribution in the watershed from sources other than

in which A is the dissolved beta activity of runoff (in micromicrocuries per liter); B, the beta activity of the sample (in micromicrocuries per liter); C, the flow of the Chicago water supply (in cubic feet per second); D, the diversion (in cubic feet per second); and cfs, the streamflow at the Peoria sampling point.

In Table 3, the activity of the runoff is estimated for the samples representing the smallest discharges of activity in the Illinois River at Peoria.

For the two days of low activity load in September 1959, data on Chicago pumpage and Lake Michigan diversion were obtained to calculate more realistic data on the runoff activity. Prior to the sample taken on September 24—10 $\mu\mu$c/l at 5,900 cfs—the Chicago filtered-water pumpage was about 400 mgd with an average activity of 3.76 $\mu\mu$c/l and an unfiltered pumpage of 900 mgd, with an activity of about 4.4 $\mu\mu$c/l. The lake diversion was reported to be 1,000 cfs with 4.4 $\mu\mu$c/l. This load was calculated to be 31,400 μc/day, and, when added to 8,900 μc/day from ground water, contributed 40,300 μc/day, with a total flow of 3,220 cfs or 5.15 $\mu\mu$c/l as a basic load. The activity of the runoff was therefore calculated to be 15.9 $\mu\mu$c/l for a 2,680-cfs runoff.

Similarly, for the sample taken on September 10—6 $\mu\mu$c/l at 4,400 cfs—the same pumpage and diversion conditions existed, but the average activity of filtered water was 3.96 $\mu\mu$c/l and the activity of raw lake water 5.8 $\mu\mu$c/l. In this instance, the runoff activity was 6.5 $\mu\mu$c/l for 1,180 cfs.

This general approach to the evaluation of data to estimate the natural activity of streams takes into account the activity load of the stream and assumes dilution or mixing of the sources of activity with rainfall and runoff having no activity or a low level of activity. It was shown that a low level of recorded activity per unit volume may not be the natural activity when no contamination is present, because a large volume of flow with little activity can constitute a much greater activity load than a small volume of flow with more significant activity per unit volume.

This approach may be criticized for a number of reasons, but it must be recognized that the minimum recorded activity does not necessarily indicate the minimum activity that may occur. Dilution by activity-free water alone would alter the minimum activity parameter. A more serious limitation of the evaluation is in the inadequacy of the determination of dissolved beta activity, both in sensitivity and accuracy. Nevertheless, as the data are the best available, the same approach has been extended to the data for other streams in Illinois; for the purpose of comparison, the streamflow is expressed in cubic feet per second per square mile. Thus, for a particular determined activity of a sample collected for a recorded streamflow, the load may be calculated in microcuries per day per square mile of watershed, and any dilution by nonactive water will decrease the measured activity in accordance with the increase in streamflow, but without change in the activity load. Also, any increase in load greater than the minimum recorded load can be related to a calculated activity of the additional streamflow or runoff.

TABLE 3

Estimates of Runoff Activity in Illinois River at Peoria

Date	Beta Activity $\mu\mu$c/l	Streamflow cfs	Beta Discharge μc/day	Runoff Activity $\mu\mu$c/l
Mar. 23, 1958	4	9,300	91,000	4.5
Mar. 26, 1958	2	10,100	49,000	1.5
Oct. 26, 1958	8	5,300	104,000	15.3
Sep. 10, 1959	6	4,400	64,000	13.6
Sep. 10, 1959	6	4,400	64,500	6.5
Sep. 24, 1959	10	5,900	144,000	15.9

The recorded activity and corresponding streamflow for samples representing the minimum calculated load at sampling points are shown in Fig. 5. For the Big Muddy River, the minimum load was represented by a sample of 24 $\mu\mu$c/l, although other samples showed 10 $\mu\mu$c/l or less, but at greater streamflows and corresponding loads.

Of approximately 550 samples, 11 samples were found to contain no dissolved beta activity. These findings occurred in only one or two samples from each of 9 of the 23 sampling points. In view of the limitations in sensitivity and precision of the determinations, these samples might be assumed to have an activity of 1 $\mu\mu$c/l or slightly more. The minimum loads in these instances are indicated by tick marks at the 1.0 $\mu\mu$c/l level in Fig. 5.

For sixteen samples each from the Ohio River and the Mississippi River, the largest watersheds, the respective minimum loads were 11.4 and 2.56 μc/day/sq mi, and the respective activity levels were 14 and 13 $\mu\mu$c/l. The range of data indicates that the minimum load in Illinois streams is certainly less than 10 μc/day/sq mi, and in sixteen of nineteen streams (about 84 per cent) other than the Illinois River, the recorded minimum load was less than 1.0 μc/day/sq mi. Twenty-five per cent of the streams have had a load less than 0.1 μc/day/sq mi; and 10 per cent, less than 0.01 μc/day/sq mi.

As a general observation, the minimum recorded load increases with increasing watershed area, owing to sustained flow contributed by runoff. The lower levels of sustained load usually appear to be associated with periods of low volume of flow for the smaller watersheds, where the sustained flow is primarily the result of ground water contribution from unconsolidated materials.

Finally, it should be recognized that the minimum recorded activities for Illinois streams and, in many instances, the corresponding minimum load as natural activity are less than the sensitivity and accuracy of the current methods of measurement of gross alpha and beta activity by proportional counters.

Acknowledgment

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Suggested Modified Aluminon Method for Aluminum Determination

Kenneth E. Shull

A paper presented on Jun. 5, 1959, at the Pennsylvania Section Meeting, Wernersville, Pa., by Kenneth E. Shull, Vice-Pres. of Research, Philadelphia Suburban Water Co., Bryn Mawr, Pa.

THE determination of small amounts of aluminum in water with accuracy and precision is desirable for several reasons. In the coagulation of water with aluminum sulfate, for example, the hydrated aluminum oxide that forms is least soluble at the isoelectric point. Sometimes this point is difficult to determine in the usual jar test series, because more than one jar will visually indicate the correct dosage. But tests for free aluminum sulfate in the filtered samples will show quite a variation among the different jars. Obviously, the one showing the smallest concentration of aluminum is the one to use.[1]

Moreover, it has been shown by such workers as Hamilton and Flentje [2] that free aluminum sulfate in the distribution system is often responsible for discolored water. Floc that sometimes precipitates in the system, especially when it is colored with material from the mains—oxides of iron and manganese and activated carbon—can be quite a nuisance. The aluminum ion will also interfere in the fluoride test.[2]

Unsatisfactory Methods

Colorimetric aluminum methods, appearing in various editions of *Standard Methods*,[3] have not been satisfactory. None has had the desired accuracy and reproducibility, and all have been subject to interference from iron, chromium, metaphosphate, fluoride, and other ions often present in water supplies. Historically, a gravimetric method did not appear until the sixth edition of *Standard Methods*. An improved hematoxylin method appeared in the eighth edition, but only under "Nonstandard Methods" in Appendix 1. This method was far from satisfactory. The sensitivity varied markedly, and the readings drifted with time. Quite often the blank had a color more intense than the zero standard. As Packham [4] has since shown, this may have been the result of the complex reaction between hematoxylin and aluminum that results in two end products.

The ninth edition of *Standard Methods* included for the first time a standard method for the colorimetric determination of aluminum. Aluminon, the ammonium salt of aurin tricarboxylic acid, was the colorimetric reagent. With several modifications, the same procedure was continued in the tenth edition. But this method also did not have the desired sensitivity and reproducibility. Readings tended to increase with time, an indication of incomplete color development.

The lack of success with both the hematoxylin and aluminon methods motivated a research project that is still continuing. Hematoxylin and other colorimetric reagents were early elimi-

nated, and research was concentrated on the aluminon method.

A questionnaire sent to 42 laboratories indicated that 22 of them were satisfied with existing methods, but that 15 others were not. Five laboratories made no comment. In 1956, the author was asked to take on the chairmanship of the Subcommittee on Aluminum of AWWA Committee 8930 P —Standard Methods for the Examination of Water, Sewage, and Industrial Wastes. This assignment was accepted willingly, for, by then, the research indicated that a method eliminating most of the unsatisfactory features of existing methods could be developed.

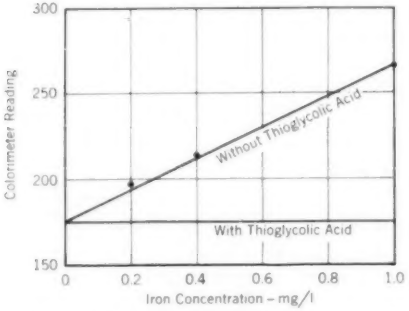

Fig. 1. Effect of Thioglycolic Acid on Iron Interference

In the presence of thioglycolic acid, the interference of iron, with regard to its intensity of color, is inhibited. The solution tested contained an aluminum concentration of 0.4 mg/l.

Development of Aluminon Test

The preparation of aluminon was first published in 1899 as a German patent.[5] The use of aluminon for determining small amounts of aluminum in various materials was developed and improved by a great many investigators, including Winter, Thrun, and Bird, in 1929[6]; Roller, in 1933[7]; Craft and Makepeace, in 1945[8]; Nelson and Bacon, in 1949[9]; Poole and Segrove, in 1955[10]; and Banerjee, in 1957.[11] Chenery,[12] in 1948, is generally given credit for showing that the interference of iron can be eliminated by the use of thioglycolic acid. This reagent, however, was actually used by Mayr and Gebauer,[13] in 1938, to hold iron in solution when making an ammoniacal separation of aluminum. In spite of this, the reagent is not in general use in methods for the determination of aluminum in water.

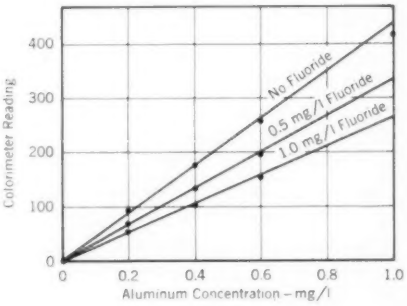

Fig. 2. Effect of Fluoride Ion on Color

Negative errors approaching 25 per cent and 49 per cent are caused by fluoride concentrations of 0.5 mg/l and 1.0 mg/l, respectively.

It was well known when this study began that ferric iron, chromium, and other ions interfere positively by forming a colored complex with aluminon. On the other hand, fluoride and metaphosphate ions interfere in a negative way by preventing the formation of aluminum lakes.

Aluminum is the third most abundant element in the earth's crust. It is an important component in a great number of minerals, and it is found in most rocks and clays. Thus, it occurs

in practically all natural water supplies as a soluble salt (aluminum sulfate), as a colloid (colloidal aluminum hydroxide or hydrated aluminum oxide), or as an insoluble compound (aluminum hydroxide, hydrated aluminum oxide, or complex aluminosilicate). It may appear also in treated water as soluble residual aluminum from alum coagulation.

If a sample contains aluminum in all of its forms, the aluminon test will determine soluble aluminum and any portion of the colloidal and insoluble aluminum compounds that go into solution at a pH of 4.0 during, and at the temperature of, the test. Treatment with concentrated hydrochloric acid will place the colloidal and insoluble aluminum hydroxide into solution. Total aluminum requires fusion with sodium carbonate or an equimolecular mixture of anhydrous potassium and sodium bicarbonates. If only soluble aluminum in a mixture is desired, filtration through a membrane filter will eliminate colloidal, insoluble, and complex aluminum compounds.

Modified Aluminon Method

The procedure finally developed by the Subcommittee on Aluminum has been tested in a representative number of laboratories. The comments received have, in general, been favorable, and a modified aluminon method has been developed that is accurate and sensitive and that has reproducible results. This method will be included in the forthcoming eleventh edition of *Standard Methods*.

1. General Discussion

1.1. *Principle.* The method is based on the fact that dilute aluminum solutions, buffered to a pH of about 4.0, produce with aluminon a red to pink lake that exhibits maximum absorption at about 525 mμ. The intensity of the developed color is influenced by the aluminum concentration, reaction time, temperature, pH, quality of the aluminon used, and concentration of the various accompanying ions in the sample.

1.2. *Interference.* Thioglycolic acid inhibits the interference of iron (Fig. 1), normal phosphate, chromium, titanium, and certain other ions. The presence of gum arabic stabilizes the colloidal color system. The addition of citric acid to a sample blank containing color or turbidity prevents the aluminum in the sample from reacting with the aluminon.

Negative errors approaching 25 per cent and 49 per cent are caused by fluoride concentrations of 0.5 mg/l and 1.0 mg/l, respectively (Fig. 2). A procedure worked out by Packham [4] for the removal of fluoride interference has been incorporated into the method and will be discussed later.

Polyphosphate ion also leads to poor results (Fig. 3). Although it will be eliminated by the treatment for fluoride removal, it can also be removed by boiling in the presence of 4 ml of 6*N* sulfuric acid. Sulfite, in excess of 10 mg/l, introduces a negative error, but it can be eliminated by oxidation with 3 per cent hydrogen peroxide. Chlorine, in concentrations greater than 0.5 mg/l, should be removed with sodium thiosulfate.

The optimum aluminum range is between 0.02 mg/l and 1.0 mg/l, but it can be extended upward by sample dilution. The photometric calibration curve conforms to Beer's Law for an aluminum concentration as large as approximately 1.0 mg/l.

1.3. *Storage of sample.* All glassware should be rinsed with hot *6N* hydrochloric acid and then with aluminum-free distilled water to avoid contamination errors. Glassware used for the first time should be treated with a strong solution of sodium hydroxide, followed by hot concentrated hydrochloric acid.

2. Apparatus

Colorimetric equipment. One of the following is required:

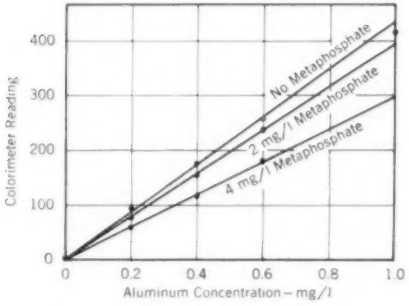

Fig. 3. Effect of Metaphosphate Ion on Color

Although metaphosphate ion will be eliminated by the treatment for fluoride removal, it can also be removed by boiling in the presence of 4 ml of 6N sulfuric acid.

a. *Spectrophotometer,* for use at 525 mμ and utilizing a light path of 1 cm or longer.

b. *Filter photometer,* providing a light path of 1 cm or longer and equipped with a green filter showing maximum transmittance between 520 mμ and 540 mμ.

c. *Nessler tubes,* matched, tall form.

3. General Reagents

All reagents should be low in aluminum concentration and be prepared with aluminum-free distilled water.

3.1. *Stock aluminum solution.* The metal (a) or the salt (b) may be used:

a. Dissolve 0.5000 g of reagent grade aluminum metal in 10 ml of concentrated hydrochloric acid by heating gently. Dilute to 1 liter in a volumetric flask with distilled water; 1 ml contains 0.5 mg of aluminum.

b. Dissolve 8.792 g of aluminum potassium sulfate [$Al_2(SO_4)\cdot K_2SO_4\cdot 24H_2O$] in distilled water, and dilute to 1 liter in a volumetric flask; 1 ml contains 0.5 mg of aluminum.

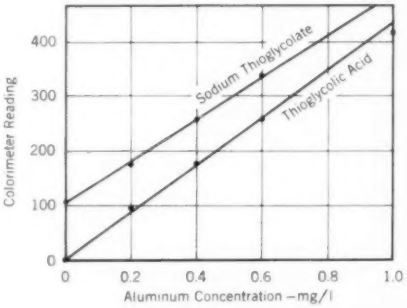

Fig. 4. Effects of Sodium Thioglycolate and Thioglycolic Acid on Color

Sodium thioglycolate significantly increased the color intensity.

3.2. *Working aluminum solution.* With distilled water, dilute 10 ml of the stock aluminum solution to 1 liter in a volumetric flask. Then 1 ml contains 0.005 mg of aluminum. This solution should always be freshly prepared.

3.3. *Paranitrophenol indicator solution.* Dissolve 1 g of the indicator in distilled water, and make up to 100 ml.

3.4. *Hydrochloric acid, 1N.* Dilute 83 ml of concentrated hydrochloric acid to 1 liter with distilled water.

3.5. *Ammonium hydroxide, 3N.* Dilute 200 ml of ammonium hydroxide to 1 liter with distilled water.

3.6. *Citric acid solution.* Dissolve 10 g of citric acid monohydrate in distilled water, and make up to 100 ml.

3.7. *Thioglycolic acid inhibitor.* Dilute 1 ml of thioglycolic acid to 100 ml with distilled water. If desired, ammonium thioglycolate may be substituted. Inasmuch as neither solution is stable, it should be made up fresh every few days. Sodium thioglycolate significantly increased the color intensity (Fig. 4).

3.8. *Aluminon buffer solution.* Dissolve separately the following reagents in approximately 100-ml portions of distilled water, and mix the resulting solutions in the order named: 133 g of ammonium acetate, 126 ml of concentrated hydrochloric acid, 0.9 g of ammonium salt of aurin tricarboxylic acid, and 10 g of gum arabic. Dilute to 1 liter with distilled water and mix. Let stand overnight, and filter through fine glass wool if any turbidity develops. The pH of the solution should be between 3.8 and 4.0. The mixed reagent should be stable for as long as 6 months.

4. Reagents for Removal of Fluoride Interference

4.1. *Sulfuric acid,* concentrated.

4.2. *Sodium carbonate,* anhydrous, analytic reagent grade powder.

4.3. *Hydrochloric acid,* concentrated.

5. General Procedure

5.1. Prepare a series of aluminum standards from 0.00 to 0.05 mg by accurately measuring the calculated volumes of working aluminum solution into 250-ml erlenmeyer flasks. Add distilled water to a total volume of approximately 50 ml.

5.2. Place two 50-ml portions of the sample, or aliquots diluted to 50 ml, in 250-ml erlenmeyer flasks.

5.3. To each flask add one drop of paranitrophenol indicator.

5.4. If the solution turns yellow, add 1*N* hydrochloric acid dropwise until the color is just discharged.

5.5. If no color is evident, add 3*N* ammonium hydroxide dropwise until a faint yellow color appears.

5.6. Proceed with the dropwise addition of the acid as before. If the sample adjusts to pH 3.8–4.0 on addition of the aluminon buffer solution, the preliminary pH adjustment can be omitted. The adjustment of the sample will occur in most instances.

5.7. If the sample contains color or turbidity, add, with mixing, 1 ml of citric acid solution to the second 50-ml sample, which serves as the sample blank.

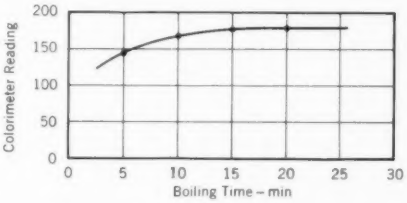

Fig. 5. Effect of Boiling on Color

The solution tested contained an aluminum concentration of 0.4 mg/l.

5.8. To each 50-ml sample, standard, and blank, add 2 ml of thioglycolic acid inhibitor, and mix.

5.9. Add 10 ml of aluminon buffer solution, using a volumetric pipet, and mix.

5.10. Place the treated samples, standards, and blanks immediately in a boiling water bath for exactly 15 min (Fig. 5). Be sure that the water continues to boil actively during the entire period of immersion and that its level is above the liquid level in the flasks. The flasks should be supported on a

perforated plate to insure intimate contact with the boiling water. Lead collars may be used to keep the flasks from tipping over.

5.11. At the end of the heating period, remove the flasks and cool them in an ice bath to a temperature between 20°C and 25°C.

5.12. Make up to 100 ml with distilled water in a volumetric flask or nessler tube. It is important that the temperature be controlled within the specified range (Fig. 6).

5.13. Read the percentage transmittance or absorbance, using a wave length of 525 mμ or a green filter

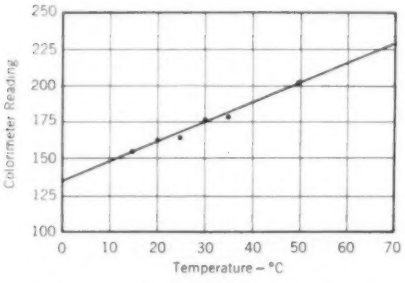

Fig. 6. Effect of Final Temperature on Color

The solution tested contained an aluminum concentration of 0.4 mg/l.

providing maximum transmittance between 520 mμ and 540 mμ. Use a blank to adjust the instrument to 100 per cent transmittance or zero absorbance to compensate for natural color and turbidity.

5.14. Plot a calibration curve of milligrams of aluminum (or milligrams of aluminum per liter) against photometric reading, and read the concentration of aluminum in the sample from the curve (Fig. 7). A new calibration curve should be plotted each time a new aluminon buffer solution is prepared.

5.15. If photometric equipment is not available, transfer the samples and standards, after they are withdrawn from the boiling water bath and cooled, to 100-ml nessler tubes, make up to the mark, and compare the color of the sample with the standards.

6. Procedure for Removal of Fluoride Interference

6.1. Place the sample in a 100-ml platinum evaporating dish, and evaporate to dryness on a steam bath or hot plate.

6.2. Add 5 ml of concentrated sulfuric acid to the residue.

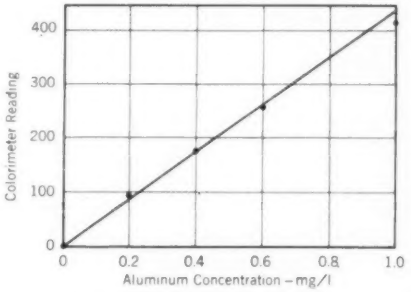

Fig. 7. Calibration Curve

A new calibration curve should be plotted each time a new aluminon buffer solution is prepared.

6.3. Carefully evaporate to dryness on a hot plate. Control the temperature to avoid spattering.

6.4. Fuse the residue with 0.5 g of sodium carbonate.

6.5. Extract the cooled cake with 10 ml of hot distilled water.

6.6. Add 5 ml of concentrated hydrochloric acid.

6.7. Heat gently for a few minutes, add 10 ml of distilled water, and wash the contents of the dish into a beaker.

6.8. Boil the solution for a few minutes, then wash the contents of the

beaker into an erlenmeyer flask, and proceed as described previously. A blank should be run, with the use of distilled water and all the reagents, including 0.5 g of sodium carbonate.

One should keep in mind that the acid-fusion treatment, although eliminating fluoride and complex metaphosphate interference, may also place certain usually insoluble aluminum compounds into solution.

7. Calculation

$$\text{mg/l Al} = \frac{\text{mg Al} \times 1{,}000}{\text{ml sample}}$$

8. Precision and Accuracy

The minimum aluminum concentration detectable by this method is 0.001 mg in a 50-ml sample. This corresponds to 0.02 mg/l.

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ABS and the Safety of Water Supplies

AASGP Committtee Report

A contribution to the Journal by the Research Steering Committee of the Technical Advisory Council of the Assn. of Am. Soap & Glycerine Producers, Inc., New York, submitted by F. J. Coughlin, R. Bell, W. K. Griesinger, W. J. Jensen, J. D. Justice, W. A. Kline, E. Paulson, J. T. Rutherford, M. V. Trexler, and H. V. Moss (chairman).

WITHIN the past 10–15 years, synthetic detergents have almost completely replaced soap in the field of heavy-duty washing products. One natural consequence of this has been the appearance of traces of detergent ingredients in sewage and, subsequently, in some surface and ground waters fed by sewage effluents. The substance most frequently encountered in water supplies is the commercial anionic surface-active agent, alkyl benzene sulfonate (ABS). Nor is this surprising, for, in terms of quantity manufactured and the number of detergent products containing it, ABS is the most important surface-active agent in use in detergents in the United States today.

The widespread use of ABS makes it appropriate to ask whether it will have any long-term effects on the health of man if consumed in trace amounts in food and water. Most of the available experimental data have been reviewed by responsible bodies or by individuals concerned with problems of public health and stream pollution. The general conclusion is typified by the views of the British Government's Committee on Synthetic Detergents,[1] who concluded that there was no evidence of ill effects from the concentrations of detergents normally found in food or water, but recommended that the possibility of long-term effects be kept under review.

It has long been known that ABS, like other anionic surface-active agents, has a low acute oral toxicity. This knowledge is based on experimentation with animals, as well as evidence of toxicity to humans through accidental ingestion. For example, the oral LD_{50},* depending on the species of animal, is variously reported to be in the range of 1.0–2.3 g per kilogram of body weight.[2–4] It is, however, the possibility of long-term or chronic effects of trace amounts of ABS which needs consideration. A possible household source of such traces, the residue left on unrinsed dishes, has been investigated.[1] Cups washed in common household detergents and drained without rinsing imparted 0.2–1.0 ppm of surface-active agent to water used to refill them. This is no more than is found in some water supplies[5] and is below the level of detection by taste. Rinsing of the cups before they were refilled resulted in less than measurable

* The LD_{50} is the amount of substance (usually expressed in grams, milligrams, or milliliters) per unit of body weight which, on the average, will kill one-half of a group of animals of a given species under given conditions.

concentrations of the surface-active agents.

Investigations With Animals

A variety of investigations aimed at detecting subacute and chronic effects of ABS have been carried out with animals, and at least one with human beings. Freeman and coworkers [6] fed a purified alkyl aryl sulfonate to six men at a rate of 100 mg/day for 4 months, or the equivalent of 2 liters of water per day containing 50 ppm ABS. The men experienced no change in weight, and only two reported any effect on their appetites. During the experiment, blood and urine analyses were normal. The same investigators fed ABS to dogs at a rate of 1 g/day for 6 months and to rats as 0.5 per cent of their diet for 65 days. Dosages as high as these produced no changes in weight, in the blood, or in other tissues of the animals. The ABS did not affect reproduction in the rats.

Woodard and Calvery [4] gave ABS to guinea pigs at a 0.2 per cent concentration (2,000 ppm) in drinking water for 6 months. Although their findings were not presented in detail, the animals apparently did not exhibit toxic symptoms, and pathological examination of tissues revealed no damage due to toxic effect of the surface-active material.

Fitzhugh and Nelson [7] made studies of both subacute and chronic toxicity to rats of several types of surface-active agents. The chronic-toxicity study did not include ABS, but when it was fed for 4 months as 0.5–1.0 per cent of the diet, the animals grew normally. Higher levels resulted in smaller weight gains, which were apparently due to decreases in the absorption of food resulting from a laxative effect induced by the ABS, rather than loss of appetite. In general, the animals showed no dislike for food containing anionic agents.

Hine and coworkers [2] have published the results of a variety of ABS toxicity studies, which include experiments with rats over a 6-month period. In concentrations of 1, 10, and 20 ppm in the diet, ABS had no effect on growth. In studies in which rats received up to half of the LD_{50} dose daily for 45 days, food intake and weight gain were equal to or greater than those of controls. Histologic examinations of tissues gave normal findings.

Hopper and coworkers [3] fed mice daily, 6 days a week, with one-tenth of the LD_{50} dose of a C_{12} and a C_{10} ABS as well as with several other anionic, cationic, and nonionic surface-active agents. They reported one death in each group of ten mice after administration of 25 such doses of ABS. There was no comment by the authors on the possible significance of these deaths, which occurred early in the experiment. Of the various surface-active agents studied under these conditions, the ABS samples appeared to be the least toxic.

Almost all other published work on subacute effects of ABS has been done on domestic animals. These have been studies of the possible nutritional effects of detergents when added to the diet of swine or poultry. The results of work with swine are particularly relevant because of the similarity of this animal's digestive system to that of man.

The growth of weanling pigs was stimulated by 0.2 per cent of ABS in the diet over a 79-day period.[8] Concentrations of 0.1 and 0.4 per cent ABS gave normal growth. Experiments in Germany [9, 10] were run to test the common practice of preparing hog feed

with dishwater from the kitchen. Groups of swine were daily fed rations mixed with 1 liter of water containing 0.15 or 0.375 per cent of one or the other of two ABS–alkyl sulfate detergent products. These concentrations were three times those recommended by the manufacturers for dishwashing. In comparison with a control group the experimental animals showed normal weight gain and feed consumption and utilization over a 5½-month period. Examination of the carcasses and internal organs and subjective analysis of the meat for any unusual taste revealed no abnormalities. In one experiment, hogs were given feed containing increasing concentrations of ABS-alkyl sulfate detergents until, at the end of approximately 7 months, they were consuming feed which had been mixed with water containing fourteen times the normal concentration of ABS in dishwater. These animals gained more weight than control animals that were given no detergent.

Metabolic studies with pigs [11] have shown that 99.5 per cent of an orally administered dose of S^{35}-labeled ABS was excreted within 8 days after ingestion, more than half of it appearing in the feces. Most of the ABS was excreted unchanged. The solubility of ABS is such that efficient excretion apparently does not require that it be metabolized.

There have been several articles on the growth-promoting effects of ABS in poultry rations.[12-17] Workers in this area have fed ABS in concentrations up to 0.2 per cent in the diet of young chickens and turkeys, and, in some cases, they have reported growth increases of the order of 1 per cent over control fowl. None of the investigators has reported any adverse effect of ABS on the health or weight of the fowl.

Current Opinions

Several reviewers of the literature have expressed opinions on significance of trace amounts of ABS in water or food. Thus, Lehman,[18] of the Food and Drug Administration, has stated that because of their low toxicity, anionic agents, including ABS, can be safely used for washing fruits and vegetables, provided that adequate rinsing follows their use. Heyroth [19] stated in 1954 that the acute oral toxicities of anionics offer "no cause for alarm," but that long-term studies up to that time were inadequate to establish their safety as additives in foodstuffs. Smyth has reported the belief [20] that the present and anticipated levels of all the detergents that are found in rivers and streams offer a wide margin of safety, from the standpoint of any long-term effects of ingestion in drinking water. The British Government's Committee on Synthetic Detergents has concluded [1] that there is no evidence pointing to any serious acute toxic effects from anionic (or nonionic) detergents. The committee further stated that published experimental data do not show ill effects from chronic exposure to detergents in food or water—an exception being gastric irritation, which may interfere with food absorption when excessive levels are fed—but recommended that the possibility of long-term effects be kept under review. AWWA Task Group 2661 P, in reporting on detergents in water supplies,[21, 22] has expressed a viewpoint similar to that of the British committee. The Food Protection Committee [23] has concluded that there are no toxic effects common to all surface-

active agents, and that surface activity is not a measure of toxicity.

Stokinger and Woodward[24] have stated recently that the anionics, as a group, are practically nontoxic, although alkyl aryl sulfonates are more toxic than other anionics. The authors suggest that "mildly toxic" organic compounds should be assigned a limiting concentration of 500 ppm in water. Although the term "mildly toxic" was not defined by the authors, ABS might be put into this or some lower-toxicity category. It is interesting to note that maximum ABS levels in sewage reaching disposal plants are reported to be less than one-thirtieth of this limit, or approximately 15 ppm,[22, 25-27] and would therefore be much lower in rivers which receive sewage in either the raw or the treated form.

Conclusion

Various investigators have considered the possible oral toxicity of ABS from the standpoint of its short-term and long-term effects. The results all indicate that man and animals can tolerate relatively high concentrations of ABS in drinking water or food without ill effect. Even in feeding studies in which concentrations of ABS reached high enough levels to produce noticeable effects, the effects generally took the form of temporary gastrointestinal disturbances resulting rather from the irritant action common to all soaps and anionic detergents than from any true toxic effects.

Although future surveillance of the whole situation is, of course, desirable, it seems definite at this time that, based on a conservative assessment, ABS can be consumed at concentrations at least several times those presently found in drinking waters without producing any long-term, physiological effects.

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Physical, Chemical, and Biologic Effects of Hexadecanol on Lake Hefner, 1958

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IN an evaporation control study made on Kids Lake (Okla.) in the summer of 1956, it was concluded that certain essential data on the effects of hexadecanol on water quality would be desirable. It was observed, for example, that certain types of bacteria appeared to increase rapidly in the presence of hexadecanol; and it was inferred that the multiplication of these forms could be attributed to the utilization of the evaporation retardant. It was further noted that there was only slight chemical change in the small lake and that the physical characteristics of the water were not greatly modified.

Preliminary Study

A study on Lake Hefner (Okla.) was planned so as to provide preliminary data on the condition of the lake prior to the time hexadecanol was added. The limnologic and bacteriologic studies of the lake, as well as surveys of bottom fauna and fish, began on Jun. 25, 1958. Five stations were established on the lake at fairly well distributed locations in order to obtain information concerning the physical, chemical, and biologic conditions in both shallow and deep water. During the preliminary study, measurements of temperature and specific conductivity were made at each station from the surface to the bottom. Samples for the determination of pH and the concentrations of carbonates, bicarbonates, sulfates, chlorides, hardness, dissolved oxygen, and carbon dioxide were collected at the surface, middle, and bottom at all of the stations. Plankton samples were collected from the surface, middle, and bottom at one station and from the surface only at the other four stations. Populations of organisms encountered were estimated in terms of areal standard units. Bottom fauna were collected from the five different stations on three occasions, the organisms being separated from the debris and mud by sifting through a standard USGS No. 40 soil sieve. The total accumulation from each station was counted and calculated in terms of organisms per square foot. Experimental gill nets, 500 ft in length, were set in different areas in the lake in order to provide an estimate of the fish population in Lake Hefner. Two 1,000-ft trammel nets were also used at the different stations in order to catch a representative sample. Bacteria samples were collected from each of the five stations at the top, middle, and bottom and were sent to a laboratory at North Texas State College for identification and counting.

The sampling and measurements continued through Jul. 7, the final laboratory work being completed on Jul. 9.

During this period the surface of the lake was devoid of hexadecanol, except for 600 lb distributed near the boat harbor on Jul. 3. The purpose of the preliminary investigation was to obtain information concerning the conditions in Lake Hefner so that any chemical, physical, or biologic changes that could possibly be attributed to the addition of hexadecanol would be apparent.

at weekly intervals, beginning on Jul. 22 and continuing for 3 months. The last addition of hexadecanol was made on Oct. 1, and it was agreed that studies would be continued after that date in order to gain information concerning the time necessary for any residual effects of the hexadecanol wear off. Thus, the results of approximately 3 months' testing, beginning near the end

TABLE 1

Physical and Chemical Data From Station 1 on Lake Hefner, Summer of 1958

Item	Jun. 28			Aug. 15			Sep. 26	
	At 1 m*	At 14 m†	At 26 m‡	At 1 m*	At 12 m§	At 24 m‡	At 1 m‖	At 23 m‖
Temperature—°C	26	25	17.1	30.55	26.6	17.2	24.4	24.4
Specific conductivity—*μmho/sq cm*	600	650	600	650	650	700	625	600
pH	8.8	8.4	7.6	8.8	8.4	7.9	8.7	8.65
CO_3—*ppm*	10	4	0	8.0	2.0	0.0	14	18
HCO_3—*ppm*	178	182	194	179	196	228	147	145
SO_4—*ppm*	94.5	92.5	93.5	105	100	100	100	90
Cl—*ppm*	62	62.8	64.3	85	87.5	90	77.5	79.8
Hardness (as $CaCO_3$)—*ppm*	192	193	200	192	196	208	190	184
O_2—*ppm*	7.4	7	1.2	8.2	5.8	0.4	8.0	7.0
CO_2—*ppm*	0	0	0	0	0	3.0	0	0

* Epilimnion.
† Thermocline.
‡ Hypolimnion.
§ Lower epilimnion.
‖ Lake homothermous.

Hexadecanol Study

After Jul. 7 hexadecanol was added to Lake Hefner on 21 days during the month. The only days during which it was not added were those when turbulence due to wave action made use of the barge impractical. A schedule was provided for continuing the investigations at intervals of approximately 2 weeks. The limnologic and bacteriologic data were collected on Jul. 28, Aug. 15 and 28, Sep. 12 and 26, and Oct. 11 and 31. Plankton counts were made at the five stations

of July and continuing through October, are reported here. There was some unmeasured loss of hexadecanol around the perimeter of the lake, owing to wave action. Also, observations were made of the consumption of hexadecanol from the surface of the lake by certain species of fish. This is a particularly interesting phenomenon, as the literature contains no mention of similar observations, so far as the author is aware. Information on the subject may be sparse because its occurrence is very rare. The movement of

the barge sometimes was slower than the spreading effect of the hexadecanol, at which times the chemical would form into strings and float for a while, later submerging. On quiet evenings or early mornings numerous channel catfish, river carp, and European carp came to the lake surface, intermittently breaking the surface film to obtain strings of the chemical for food. That hexadecanol may be consumed has been shown by work at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio. What attracted the large numbers of fish to the surface is not known, however, although it is speculated that the heavy layer of hexadecanol may have produced peculiar lighting effects below, thus attracting the fish. Once the fish began to consume the hexadecanol they seemed to develop a great enthusiasm for it. When the water was rough, there was no fish population apparent at the surface, although near the riprap one could observe large schools of mixed species of fish feeding on the strings of hexadecanol that were caught in the undertow and, consequently, carried under water a slight distance away from the retaining dam.

Data From Preliminary Study

At the time the investigation on Lake Hefner was begun, summer stratification had already started. Station 1 was about the only area of intense investigation that had a rather stable thermocline. On Jun. 28 the physicochemical data from Station 1 indicated a condition of thermal stratification typical of reservoirs in the Southwest. The top of the thermocline (stratum of temperature discontinuity) was near 17 m and the bottom appeared to be at 19 m. The hypolimnion (lower stratum) extended to the bottom, which was to a depth of 26 m. The specific conductivity was higher through the thermocline (and just above it) than in the epilimnion (upper stratum) or the hypolimnion (Table 1). The dense layer was observed, not only at this period, but until summer stagnation terminated. Oxygen depletion down to a low concentration occurred in the hypolimnion, and free carbon dioxide was obtainable only in that stratum. Actually there was little difference in water quality on the surface and the bottom. As the other stations did not show complete stratification, one may conclude that a depth of 12 m, which was about maximum for any other station, had approximately the chemical characteristics in Table 1. On occasions during the first 2 weeks there were variations in oxygen content, but the other characteristics, including temperature, did not alter greatly.

Bottom Fauna. Because previous investigations on the effects of hexadecanol on lake biota had been very informative, studies of the bottom fauna were conducted. Several samplings from Station 1 uncovered an average of only two organisms per square foot. Even though several square feet were sampled with different types of dredges, the population was insufficient to warrant a continuation of the study, and bottom-fauna investigations were discontinued.

Bacteria. Samples were collected from the various stations for qualitative and quantitative determination of bacteria as shown in Table 2. *Pseudomonas* and *Alcaligenes*, the two organisms that were observed to increase in the Kids Lake study, were not recovered from the top or middle at any station on Lake Hefner, but were ob-

tained from the bottom samples. Because these organisms are frequently associated with soil, their presence was anticipated; and if the bottom had not beeen roiled when samples were collected, it is highly probable that these organisms would not have been discovered in the preliminary studies. The bacterial flora appeared quite normal, and, when compared with the flora of similar lakes in the area, the populations were found to be relatively low. Two sets of samples were taken during the early period of study so as to be certain of the general bacterial population. As there was little difference in the total counts, Table 2 is quite representative of the population prior to the time the hexadecanol was added.

TABLE 2

Bacteriologic Data for Lake Hefner, Jun. 27, 1958

Organism	Top					Middle					Bottom				
	Station					Station					Station				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Organisms Count—*No./ml*														
Actinomycetes	4	12	24			6				6			2		12
Aerobacter			160	16	12	32			32	120	300				*
Alcaligenes											174	12	1,600	*	*
Bacillus	4	36	8	74	8	12		16	28	150	8	60	104		
Fungi		4				6		2			4	2			
Pseudomonas											78	16	2,000	*	*
Staphylococcus			328		1,700	36		48	92	12	34				

* Too numerous to be counted.

Plankton. There is nothing in the literature to indicate that hexadecanol has a direct effect on any of the plankton organisms. As knowledge of these organisms is important in water supplies, a study was undertaken in order to get data on the types of organisms present and their abundance. Each station was sampled four times between Jun. 25 and Jul. 9, and an average count was assembled so that any unusual increase or decrease could be readily discerned (Table 3). The Oklahoma City Water Department has been making complete plankton counts for a number of years. Therefore, data were available for comparison to determine whether the plankton counts procured during the early study period differed from previous counts taken from Lake Hefner. Both the types of organisms present and their relative abundance were in fairly close agreement with the records of previous years for the latter part of June and the early part of July. The total plankton count for the surface samples at Station 1 was, on the average, 224 areal units. The average during the previous 7 years had been 194, except for two sporadic blooms of unicellular chlorophyta; otherwise the composition of the plankton organisms was similar. Thus

few, if any, unusual characteristics were brought out in the plankton studies for the period under consideration.

Fish. In order to obtain a complete picture of the general biota of the lake, the fish taken by nets were counted, weighed, measured, and identified. Unfortunately, it was not possible to make similar investigations at the conclusion of the experimental period, although the results of previous studies of the fish population in Lake Hefner during the past seven summers are very similar to those found in 1958. Because it had already been shown that hexadecanol was not toxic to fish, no reduction in the fish population was anticipated. The author regrets, however, that studies could not be made in the latter part of September, as observations of the fish feeding on hexadecanol might have demonstrated some interesting changes either in the fish composition or in the average condition of some of the species.

Addition of Hexadecanol

The first addition of enough hexadecanol to form a monomolecular film over most of Lake Hefner was made on the morning of Jul. 8. During the next 3-week period a total of 12,860 lb was added to the lake. As it was desirable to obtain as many limnologic data as possible on the effects of hexadecanol on chemical quality, a detailed study was made at 2-week intervals. It is not necessary to include all data from this study but only those that represent specific periods during the investigation. More than 20,000 lb of hexadecanol had been added to Lake Hefner by Aug. 16, and data for that date were chosen for comparison with data recorded before the application of hexadecanol.

Physicochemical Effects

As can be seen from Table 1, there were no basic changes, except for a lowering of the surface of the thermocline. In the preliminary studies the thermocline started at a depth of approximately 17 m. On Aug. 15 the top of thermocline was approximately 20 m deep. The thermocline proper was only 4 m thick on the latter date, the lower 2 m forming the hypolimnion. It is possible that the two sets of samples secured from Station 1 were not from the same specific area, as wave action frequently moved the sampling boat and no buoys were available for use as permanent markers. The boat may have been on the edge of the deep water rather than in the center. This is not important, however, as a general perusal of the data reveals no changes in water quality.

TABLE 3

Plankton Counts for Lake Hefner, Summer of 1958

Date	Plankton Count *areal standard units/ml*
Jun. 25–Jul. 9	224*
Aug. 14	220
Sep. 5	520
Sep. 25	552

* Two-week average.

Thermal stratification in Lake Hefner ordinarily terminates near Sep. 1, after which time the lake remains homothermous until the period of summer stagnation the next year. The physicochemical data secured on Sep. 26 (Table 1) indicated a homothermous condition as well as an almost uniform salinity from surface to bottom. It is apparent that during the turnover the minerals are more evenly distributed

throughout the lake, and it would appear that the water quality actually improves. The dilution of the minerals may be attributed to the addition of water to Lake Hefner. It is concluded from the observations throughout the summer and fall that hexadecanol had no deleterious effect on chemical quality of the water. It is recalled that this study continued through October. The only alteration in the general conditions found in September was a lowering in the water temperature.

Effects on Plankton

During the preliminary study period, plankton counts were made on samples taken from the surface, middle, and bottom at Station 1 and from the surface at the other stations. Observations were continued in order to discern any unusual changes in plankton. As the hexadecanol formed numerous strings, and in many instances sank beneath the surface of the water, its effects as a nutritional stimulant for general planktonic development could be readily studied. In addition, the southerly winds produced a rather heavy deposit of hexadecanol around the perimeter of the lake. From time to time the changing winds produced waves, which washed over the deposited hexadecanol. This afforded an excellent opportunity for observations of the effects of this compound as a nutrient for various types of biota. As data were available on the usual physicochemical conditions of Lake Hefner around the middle of August, a plankton count was made on the surface at Station 1 on or about the same date after the addition of hexadecanol. The population was about the same as that found in late June and early July (Table 3), and the composition of organisms had altered only slightly. The fall turnover in Lake Hefner occurred before Sep. 5, and a plankton increase became evident in a short time. Table 3, which gives the count at Station 1, shows a definite increase in a period of about 3 weeks.

The problem of plankton blooms in Southwestern reservoirs has not been studied in great detail. One reservoir does not appear to duplicate another, either in the prevalence of organisms or in the makeup of the population. On the surface it might appear that the hexadecanol was responsible for producing the increase of organisms in Lake Hefner, particularly the blue-green algae. It is generally known that blue-green algae may prove detrimental to a water supply because of their high protein content and because they provide nutrients for taste- and odor-producing actinomycetes. Fortunately, data on Lake Hefner are available for a number of years, and some conclusions may be readily drawn concerning the situation in 1958 as compared to previous years. The greatest bloom of algae occurred on Sep. 25, 1958, at Station 1. From a comparison

TABLE 4

Late September Plankton Counts for Lake Hefner and Lake Overholser, 1953–58*

Year	Plankton Count—*No./ml*	
	Lake Hefner	Lake Overholser
1953	190	17,040
1954	332	528
1955	428	88
1956	144	488
1957	152	172
1958	552	340
Avg	299	3,103

* All counts made between Sep. 22 and Sep. 28.

of the data with those of previous years (Table 4) the effect of hexadecanol as a source of nourishment for plankton may be evaluated. The average counts, including 1958, were 299. During 1958, therefore, the count was somewhat higher than the average for the years cited. The organisms of greatest interest, however, are the blue-green algae. During 1953–57 count for the blue-green algae averaged 250 areal standard units; for 1958, it was 280. It does not appear, therefore, that hexadecanol is readily utilized by this group of organisms. It is probably more conclusive to compare these data with those for a similar lake on similar dates. Lake Overholser was not treated with hexadecanol. Although it is situated on the bypass of the North Canadian River, the water it receives is somewhat similar to that in Lake Hefner. To be sure, on occasions it would receive water of greater nutritive content; at other times, very muddy inflowing water might reduce the plankton count to a low concentration. The average for the same period in Lake Overholser was 3,636 areal standard units, of which the majority was due to the bloom of blue-green algae during 1953. Had this bloom occurred on Lake Hefner in 1958, there might be some reason to attribute a nutritive effect to hexadecanol. Other conditions being equal, however, it would appear that the utilization of this compound is not accomplished directly by normal plankton to any noticeable extent.

It is noteworthy that some of the hexadecanol deposited around the perimeter of Lake Hefner is still present. On Jan. 21, 1959, a survey was made of the shore line of Lake Hefner, which revealed deposits of the material still available. Prior to the end of the growing season certain sedges grew more profusely in and around the hexadecanol deposits. Ordinarily this would not be of any particular concern, as these plants are frequently found above and below the waterline in Southwestern reservoirs. In Lake Hefner, however, the occurrence of dense growths of sedges, particularly in the fall, is considered undesirable because these types of vegetation may serve as nutrient sources for taste- and odor-producing actinomycetes. It was also observed that floating mats of vegetation mixed with the hexadecanol were carried shoreward and deposited either on the riprap or the muddy shoreline of the lake. Invariably these areas contained zones of unusual actinomycete activity and consequently were sources for the production of taste-and-odor compounds. It should be recalled that such areas are only of importance when they become submerged due to rising water levels or, more especially, when rainfall occurs, so that the inflowing water from such contaminated regions adds odoriferous products to the surface waters. It is possible that the bacteria growing on the hexadecanol may have made compounds available, which, along with the entangled vegetation, resulted in the copious growths of the actinomycetes. Actinomycetes may ordinarily grow around the perimeter of Lake Hefner, but the precautions taken in chemical treatment during 1956–57 reduced the growth to a minimum. The same treatment in 1958, however, did not appear to be effective on the odor-producing organisms growing on the admixture of vegetation and hexadecanol.

Effects on Bacteria

During the preliminary study period the bacterial counts at the five stations

on Lake Hefner were reasonably low, except in the bottom areas. Following the addition of hexadecanol, the bacterial population began to increase (Fig. 1). The organisms first to respond were *Aerobacter*, which attained their maximum concentration sometime between Aug. 17 and Aug. 29. Because the samples for bacterial studies were taken at approximately 2-week intervals, the amount of hexadecanol added is shown in the block columns on

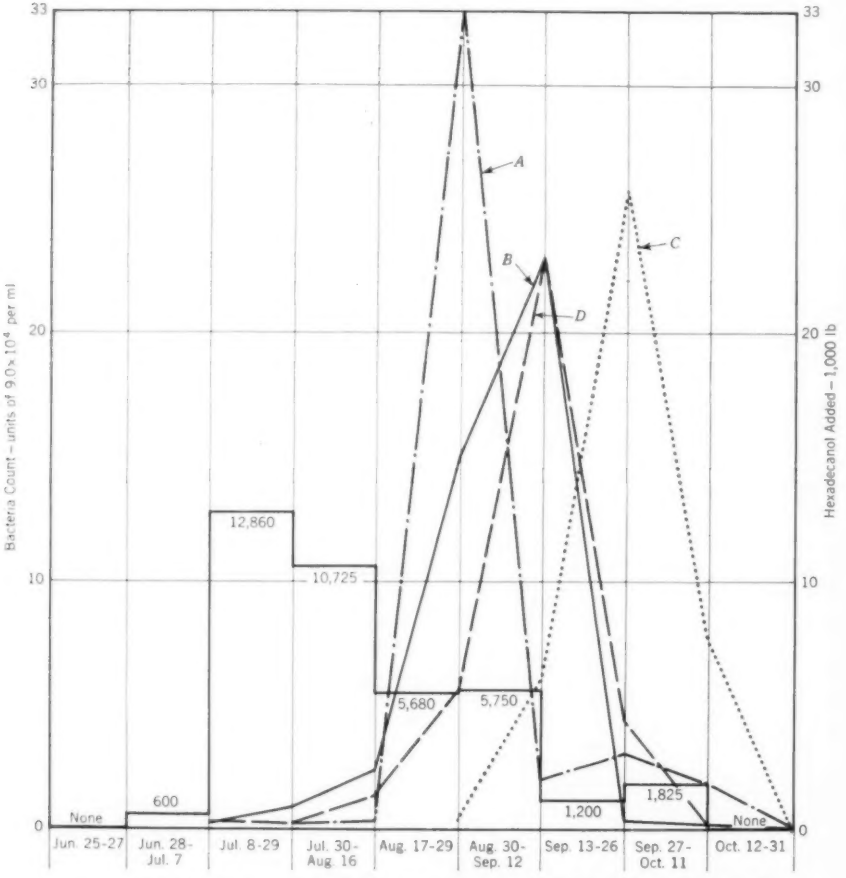

Fig. 1. Relationship of Hexadecanol Additions to Total Colony Counts for Organisms in Lake Hefner, June–October 1958

Curves, A, B, C, *and* D *represent counts at 2-week intervals for* Aerobacter, Pseudomonas, Bacillus, *and* Alcaligenes, *respectively. The step graph represents hexadecanol additions for the same 2-week periods (figures accompanying each level are amounts added, in pounds).*

a basis similar to the sampling schedule. The density of the population was not maintained, owing to the reduction in available hexadecanol, so that after 2 weeks *Aerobacter* had diminished to a low concentration. *Pseudomonas* began to respond to the nutrients in the hexadecanol soon after the original additions were made, and they attained a maximum population sometime between Aug. 30 and Sep. 12. The population diminished more slowly than *Aerobacter*, almost disappearing by the latter part of September. *Alcaligenes* responded more slowly than *Pseudomonas* but attained a maximum concentration at a similar time. The last group of bacteria to show a definite increase was the *Bacillus* group, containing several species; and it is possible that *Flavobacterium* was a member of the group, as several pigmented forms appeared in samples taken in July and August.[1] No attempts at detailed identification were made in this study. The maximum population in the *Bacillus* group was attained near the middle of September, followed by a disappearance on or about the last of October.

The limnetic distribution of the different genera of bacteria was interesting since certain stations showed an even distribution from surface to bottom, whereas others very obviously had a greater concentration near the surface or near the bottom. If any specific bacterial population attained concentrations in excess of 1,000,000 organisms per milliliter on either the surface or the bottom, they were also cultured from the middle. Samples collected on Aug. 29 and Sep. 12 showed the greatest density in population. *Pseudomonas* attained counts in excess of 4,000,000 per milliliter, as did *Aerobacter* and *Alcaligenes*. The actinomycetes did not exceed 300,000 per milliliter and this was at one station on Aug. 29. The rate of growth of the microorganisms in Lake Hefner resembled very closely the laboratory findings that have been carried on at North Texas State College laboratories during the past 2 years.[2] It appears that, under optimum conditions, most of the bacteria encountered reached a maximum population in approximately 6 weeks. Normally they increase from 10 organisms per milliliter to as many as 10,000,000 in that time. If hexadecanol is continued as a source of nutrition, maintenance of the population appears very good. If the hexadecanol is removed, there is an obvious and rapid decrease in organisms. This is usually accomplished in 3 weeks. It is therefore noteworthy that by the end of October the bacteria had decreased to a very low concentration; by Nov. 15, they were lower than they were during the first week of July.

The total bacteria count, including all genera as well as actinomycete spores, rose to a level of 15,000,000 per milliliter at certain stations on Lake Hefner. Figure 1 gives an average count of all stations and all levels, including samples collected at the top, middle, and bottom, and, therefore, does not reveal maximum concentrations. Raw water entering the Lake Hefner filtration plant showed bacterial counts as high as 10,000,000 per milliliter. Although these organisms may not be of public health importance, it must be concluded that the chlorine demand would of necessity be increased. Studies on the finished water during the same period—late August to early September—showed bacterial

counts of 1,000 per milliliter. Admittedly, the Lake Hefner Water Plant was doing a fair job in reducing the bacterial population. Possibly these results indicate a need for further studies on water supply reservoirs before the use of hexadecanol is approved, as only a few genera were isolated from the waters of Lake Hefner and in one instance different from those in the Cincinnati study.[1]

It should be mentioned that in the latter part of August bacterial studies were also made on Lake Overholser; it was found that the same genera of organisms were available as in Lake Hefner, although their concentrations did not exceed 1,600 per milliliter. It would appear rather definite that hexadecanol contributed to the growth of the organisms mentioned; and had the film been maintained continuously, the concentration of bacteria would doubtless have been higher.

Preparatory to the Lake Hefner experiment, a request was made to the Taft Center to procure samples of the carbon removed from the filters on the raw-water intake and finished-water outlet from the Lake Hefner plant. In compliance with the request, samples were forwarded. Granules of carbon from the raw-water filters were placed on slightly warm tryptocase-soy agar and observed for bacterial growth. At the same time selected granules of carbon were aseptically placed in 100-ml portions of sterile water. The samples were agitated on a shaker for 1 hr and subsequently plated on similar media. The same procedure was followed with carbon samples taken from the finished water. At the same time one or two carbon granules were placed in thioglycollate broth in order to obtain organisms for identification. The carbon granules from the raw-water filter contained the same genera of organisms that were present in the lake; and, as far as could be ascertained, the average-sized granule of carbon in 100 ml of sterile water liberated approximately 2,500,000 organisms per milliliter. The carbon from the finished water liberated approximately 10,000 organisms per milliliter.

Residual Hexadecanol

Observations of the shoreline on Jan. 21, 1959, revealed that deposits of hexadecanol resulting from the treatments made between Jul. 3 and Oct. 1, 1958, were still present. Consequently, observations were continued, and on Apr. 3, 1959, it was noted that the apparent quantity of the material (at that time well above the waterline) appeared basically the same as in January and was apparently present in the same concentration as in Oct. 1958. Although the locations of these deposits were not plotted on maps and their specific weights were not determined, rather detailed field notes describing the locations and extent of deposition of hexadecanol along the shore are sufficiently accurate to justify some conclusions concerning the persistence of this compound.

Since the Apr. 3 observation, water introduced into Lake Hefner has inundated a portion of the deposits. More of the residual hexadecanol was under water than above water. This is because during the time of application the level of Lake Hefner was falling, and, depending upon the quantities of hexadecanol added, variable deposits accumulated. On May 1, 1959, it was observed that a small portion of the hexadecanol broke loose and appeared as granules or flakes floating on the

surface of Lake Hefner. The major underwater deposits had not yet broken loose. It appears, therefore, that hexadecanol deposited in the summer and early fall remains intact and is not greatly reduced. From past experience, it could be assumed that the hexadecanol now inundated will probably be consumed by biologic activity. When the water temperature increases, actinomycete counts, which are being made continuously, may readily reveal the importance of hexadecanol in the biotic cycles of the lake.

It is highly probable that the observations made on the deposition of hexadecanol in Lake Hefner are incomplete. A large portion of the hexadecanol blown from Lake Hefner accumulated on or in the riprap of the dam. The deposited hexadecanol ultimately was moved by wave action into the spaces between the rocks composing the riprap and, therefore, was not visually apparent. Thus, observations were possible only on the soil shoreline, which is on the east, south, and a small portion of the west side of the lake. As the prevailing winds were southerly, southwesterly, or easterly, a large percentage of the material deposited around the lake margin could not be observed. It could be assumed, however, that the hexadecanol deposited in the riprap remains available to furnish nutrients for numerous microorganisms.

Biologic Significance of Hexadecanol

It may be that a continued study of both actinomycetes and bacterial populations is in order if the complete biologic significance of hexadecanol, in both its film and its residual forms, is to be known. The waxy consistency of the hexadecanol has not changed perceptibly, although it is apparent from its action in a water solution that the outside portion has been degraded to weak acids that are slowly miscible in water and, on extraction with chloroform, show numerous weak acid groups on the infrared spectrophotometer. From this it can be assumed that the hexadecanol will not again be available to form a monomolecular film, as it will probably degrade into some similar weak organic acids, which will be consumed by microorganisms. Just how much of a problem it might be to control the organisms that consume deposits of slightly oxidized hexadecanol remains to be ascertained.

At present, it appears that the destruction of hexadecanol by bacteria is more of an economic problem than a public health consideration. After the water attains a temperature of 26°C, the amount of hexadecanol required by the bacteria appears to increase in a geometric ratio. Consequently, during the first 3 weeks of application, the bacteria in any given area appear to require an amount of hexadecanol equal to the quantity necessary to cover that area of water. During the next 3 weeks, twice the amount is demanded. During the third 3 weeks, four times the amount is demanded, and so on. The most encouraging observation appears to be the rapid decrease in bacteria when the hexadecanol is removed. Again, the decrease appears to take approximately 3 weeks. Consequently, if economics is an important consideration in evaporation control, hexadecanol should probably be added for a period of 6 weeks followed by a 3-week lapse before another application—provided, of course, that the various disinfecting agents that have been or are yet to be investigated fail to be effective in reducing the bac-

terial population to an acceptable concentration.[1]

Acknowledgment

The cooperation of Murray B. Cunningham, Frank S. Taylor, and John S. McReynolds, of the Oklahoma City Water Department, all of whom collaborated in the preparation of this article; of the other consultants; and of members of the 1958 limnology class of North Texas State College, Denton, Tex., who assembled the data, is gratefully acknowledged.

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Reliability of MPN Indexes of Coliform Organisms

Ralph E. Noble

A contribution to the Journal by Ralph E. Noble, Water Bacteriologist IV, South District Filtration Plant, Dept. of Water & Sewers, Chicago, Ill.

THE MPN method is accepted for estimating the coliform population in water, and is set forth in *Standard Methods*.[1] Analyses of variance procedures are available in elementary texts on statistical methods.[2] These two standard procedures were combined to study the interpretation of MPN values.

Shortly after the beginning of this study, a similar project was undertaken by J. A. McCarthy, chief of the Lawrence (Mass.) Experiment Station. The data from Lawrence were made available for comparison.

As a result of the experimental and statistical evidence obtained, it is possible for bacteriologists to: (1) have more confidence in their data; (2) compare the reliability of data from different laboratories working with the same general type of source material; (3) realize that unusual fluctuations in coliform indexes may be caused by factors other than laboratory technique; and (4) determine, more effectively, the characteristics of the environmental changes that cause these fluctuations. The use of duplicate MPN determinations from the same source is the most important change in procedure introduced in both projects. The customary examination of individual MPN's and their averages was not made. The use of duplicate MPN's and duplicate samples, however, made it possible to investigate the variation characteristic of successive steps in the sampling and laboratory techniques. These techniques and methods of interpretation made it possible to detect changes in the coliform population and to interpret the changes more effectively.

Sources of Variation

The projects were undertaken to isolate and study the effect of four factors or sources contributing to the variability of MPN indexes of coliform organisms. The variability has confused interpretation of MPN's in relation to the rating and control of water supplies. The four factors are:

1. *Day-to-day variation* of the coliform population in the water supply at the sampling point

2. *Within-the-day variation* * of the coliform population in response to factors associated with time of day—that is, forenoon as opposed to afternoon

3. *Source duplicates,* or the variation characteristics of estimates of the coliform population in duplicate samples taken simultaneously from the same sampling point

4. *Laboratory duplicates,* or the variation expected when duplicate

* Chicago series only.

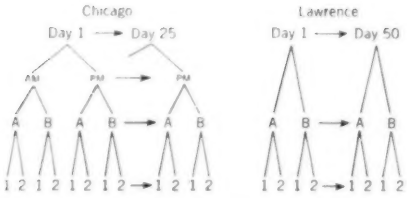

Fig. 1. Design of Experiments at Lawrence and Chicago

The basic experimental unit was repeated on each of 25 days in the Chicago series of experiments on Lake Michigan water, and on each of 50 days in the Lawrence experiments on pond water.

MPN's are obtained from one sample. This variation is characteristic of the laboratory technique and is included in every estimate of coliform organisms made in the laboratory.

Although variation in coliform organism indexes related to these factors has been recognized to some extent, the usual practice of determining one MPN per sample has not permitted separation and identification of the components of variation contributed by each of these factors. Hence, interpretation of MPN's has ranged from a complete neglect of the possible influence of sampling variation to the assumption that the variation in a series, based on one MPN each day, is entirely the result of the instability of the test or faulty laboratory technique.

Experimental Design

A study of the variation associated with standard indexes of coliform organisms is a study of the precision or reproducibility of MPN data. At least duplicate determinations are required to obtain this measure of reproducibility for each of the sources of variation specified. A single day constituted the basic experimental unit. In the Chicago series only, an AM and a PM sampling provided a measure of the variation in the level of coliform organisms during that day. In both series, duplicate source samples were obtained at each sampling time, and duplicate MPN determinations were made on each sample brought to the laboratory. This unit provided information regarding the characteristic variation associated with the specified sources. The basic experimental unit was repeated on each of 25 days in the Chicago series and on each of 50 days in the Lawrence series, to obtain information on the day-to-day changes in coliform population related to the first source of variation, day to day. The experimental designs for the work conducted at Lawrence, Mass., and Chicago are shown in Fig. 1. The degrees of freedom for each source of variation at both places are shown in Table 1.

Sampling and Procedure

Duplicate source samples of untreated water from Lake Michigan were collected in the forenoon and, again, in the afternoon on each of 25

TABLE 1

Degrees of Freedom for Each Source of Variation in Chicago and Lawrence Experiments

Source of Variation	Degrees of Freedom
Chicago	
Day to day	24
Within the day (AM-PM)	25
Source duplicates	50
Laboratory duplicates	100
Lawrence	
Day to day	49
Within the day (AM-PM)	*
Source duplicates	50
Laboratory duplicates	100

* AM and PM samplings were not taken at Lawrence.

days during Oct. 18–Nov. 28, 1951. Each pair of source samples, A and B, was shaken 25 times. Each source sample was immediately distributed into two, sterile, 4-oz bottles. This provided standard Subsamples A1 and A2, and B1 and B2, respectively. The collection and subdivision of each pair of source samples, in both the forenoon and afternoon, were completed within 90 sec. The four subsamples were delivered to the laboratory where they were planted promptly according to the procedure described in *Standard Methods* [3] for determining the MPN of coliform organisms per 100 ml. Duplicate sets of a five-tube, four-bank, decimal dilution series were planted from each sample for this purpose.

With the exception of the first source of variation, day to day, the study of the remaining three sources was based on the difference between duplicate determinations. Consequently, the analysis and interpretation of these data were treated primarily from the viewpoint of differences. Each individual difference studied is associated with one degree of freedom.

TABLE 2

MPN of Coliform Organisms per 100 ml—Specimen Data

Part 1		Sample A		Sample B	
Date—*1951*	Time	A1	A2	B1	B2
Oct. 22	AM	2.0	4.5	2.0	<2.0
	PM	31.0	49.0	42.0	49.0
Oct. 26	AM	49.0	49.0	33.0	45.0
	PM	1,300.0	330.0	490.0	790.0

Part 2		Log MPN per 100 ml (plus code of 2.0000)						
		Sample A			Sample B			
Date—*1951*	Time	A1	A2	A1+A2	B1	B2	B1+B2	A+B
Oct. 22	AM	2.3010	2.6532	4.9542	2.3010	1.0000	3.3010	8.2552
	PM	3.4914	3.6902	7.1816	3.6232	3.6902	7.3134	14.4950
Oct. 26	AM	3.6902	3.6902	7.3804	3.5185	3.6532	7.1717	14.5521
	PM	5.1139	4.5185	9.6324	4.6902	4.8976	9.5878	19.2202

Part 3	Avg of Coded Logarithms			Avg Decoded and Converted to MPN		
Date—*1951*	AM	PM	Day	AM	PM	Day
Oct. 22	2.0638	3.6238	2.8438	1.2	42.0	7.0
Oct. 26	3.6380	4.8050	4.2215	43.0	640.0	170.0

The two MPN's (A1 and A2 or B1 and B2) from each source sample (A and B) were combined to provide an estimate of the coliform population in that source sample. Similarly, all the data from each source sample were combined to estimate the coliform population at the sampling point in the forenoon or afternoon of each day.

Finally, the estimate of the coliform population, at the designated sampling point in Lake Michigan for a given day, was based on all eight MPN's obtained, as indicated in the experimental design. The differences within each pair of duplicate determinations—namely, laboratory, source samples, or AM and PM samplings—provide the measures of reproducibility among AM and PM estimates of the coliform population is considered, it is unlikely that these variances will be consistently smaller than the variance of the difference between estimates from duplicate source samples.

Presentation of Data

According to fundamental bacteriology, both the growth and death phases

TABLE 3

Analysis of Variance at Chicago and Lawrence

Source of Variation	Degrees of Freedom	Mean Square	F-Test 1 AM-PM Variation Considered as Error	F-Test 2 Source Duplicate Variation Considered as Error	F-Test 3 Laboratory Duplicate Variation Considered as Error
Chicago Series					
Day to day	24	1.6105	2.1*	11.46**	28.97**
AM-PM	25	0.7410	↑	5.27**	13.27**
Source duplicates	50	0.1405	—	↑	2.53**
Laboratory duplicates	100	0.0556	—	—	↑
Total	199				
Lawrence Series					
Day to day	49	1.4867		25.03**	29.90**
Source duplicates	50	0.0590		↑	1.19
Laboratory duplicates	100	0.0497		—	↑
Total	199				

* F-test significant at the 5 per cent level of probability.
** F-test significant at the 1 per cent level of probability.

MPN determinations at that sampling level.

The variation characteristic of each source is important. It is inconceivable that, in general, the variance of the difference between single MPN's from each of two different samples (A and B) will be less than the variance of the difference between duplicate MPN's from a single sample. Similarly, when the variance of the differences between

of bacterial populations may occur at logarithmic rates until equilibrium is reached. In addition, the standard MPN test procedure is based on a logarithmic principle. For these reasons, these data were transformed to logarithms for statistical analysis.

Table 2, Part 2, shows the data in Part 1 converted to logarithms (to the base 10) and, for convenience, coded by adding 2.0000 to each logarithmic

value. The minimum positive index obtainable with five test portions, in each of four dilutions, is 2.0 per 100 ml, when there are no "skips." In this study, MPN's of less than 2.0 were assigned an arbitrary value of 0.1 to avoid interpreting the reading as a complete absence of coliform organisms in the supply.

Part 3 was added to facilitate the interpretation of the averages of these logarithms by subtracting the code of 2.0000 and reconverting the result to MPN values. These MPN's are the geometric averages of the appropriate MPN determinations in Part 1 of the table.

Analysis of Variance

The data were submitted to analysis of variance to obtain measures of the variation associated with each of the four sources of variation under consideration. In these data, analysis of variance provided a single figure, a mean square, to express the variation associated with each sampling classification—namely, day to day, AM to PM (Chicago series), source duplicates, and laboratory duplicates. These four mean squares were evaluated to study the reproducibility of coliform organism indexes.

Chicago Series

The estimate of the coliform organism population in the water supply for a given day was calculated from the sum of all the logarithms of the MPN's obtained in the AM sampling, plus all the logarithms of the MPN's from the PM sampling—that is:

$$\mathrm{CPD}_1 = (\mathrm{A1} + \mathrm{A2} + \mathrm{B1} + \mathrm{B2})_{\mathrm{AM}_1} + (\mathrm{A1} + \mathrm{A2} + \mathrm{B1} + \mathrm{B2})_{\mathrm{PM}_1}$$

in which CPD_1 is the coliform population for Day 1. Twenty-five different estimates of the coliform populations were obtained in the Chicago study.

The mean square for day-to-day differences in the populations was calculated from the following formula:

$$\left[\frac{(\mathrm{CPD}_1)^2 + (\mathrm{CPD}_2)^2 \cdots + (\mathrm{CPD}_{25})^2}{8\ \mathrm{MPN's}} - \frac{(\mathrm{CPD}_1 + \mathrm{CPD}_2 \cdots + \mathrm{CPD}_{25})^2}{8\ \mathrm{MPN's\ (25\ days)}}\right] \div 24\ \mathrm{degrees\ of\ freedom} = \frac{38.6511}{24} = 1.6105.$$

The logarithms of the four MPN's, A1 + A2 + B1 + B2, were included in each estimate of the coliform population sampled in the forenoon or in the afternoon. For convenience, the mean square for differences between AM and PM population estimates was calculated as follows:

$$\Sigma[(\mathrm{A1} + \mathrm{A2} + \mathrm{B1} + \mathrm{B2})_{\mathrm{AM}} - (\mathrm{A1} - \mathrm{A2} - \mathrm{B1} - \mathrm{B2})_{\mathrm{PM}}]^2 \div 2(4\ \mathrm{MPN's\ per\ AM\ or\ PM})\ (25\ \mathrm{pairs}) = \frac{148.1903}{200} = 0.7410.$$

Similarly, the estimate of the population in a given source sample was calculated from the sum of the logarithms of the two MPN's from that sample. For convenience, the mean square for differences between duplicate source samples was calculated from the following formula:

$$\frac{\Sigma[(\mathrm{A1} + \mathrm{A2}) - (\mathrm{B1} + \mathrm{B2})]^2}{2(2\ \mathrm{MPN's\ per\ sample})\ (50\ \mathrm{pairs})} = \frac{28.0943}{200} = 0.1405.$$

The mean square for laboratory duplicates was calculated from the difference between the logarithms of the duplicate MPN's from each source sample—that is, log MPN A1 − log MPN A2, or log MPN B1 − log MPN B2, as indicated in the experimental

design in Fig. 1. The following formula was used to calculate the mean square for laboratory duplicates:

$$\frac{\Sigma(A1 - A2)^2 + \Sigma(B1 - B2)^2}{2(50 \text{ pairs A}) + 2(50 \text{ pairs B})} = \frac{11.1166}{200} = 0.0556.$$

Lawrence Series

The series of data from Lawrence, Mass., was analyzed in the same way as that from Chicago, with the exception that the logarithms of two MPN's (A1 and A2 or B1 and B2) from each of the two source samples, A and B, provided the estimate for the coliform population for each day, rather than the AM or PM estimates, as in the Chicago study. Hence, the mean square for day-to-day changes in the coliform population at Lawrence was calculated from a series of 50 sums of the logarithms of the MPN's from aliquots A1–A2–B1–B2. The following formula was used to calculate the mean square for day-to-day variation:

$$\left[\frac{(CPD_1')^2 + (CPD_2')^2 \cdots + (CPD_{50}')^2}{4 \text{ MPN's}} - \frac{(CPD_1' + CPD_2' \cdots + CPD_{50}')^2}{(4 \text{ MPN's})\ (50 \text{ days})}\right] \div 49 \text{ degrees of freedom} = \frac{72.8485}{49} = 1.4867$$

in which CPD_1' is the coliform population for Day 1'. The experimental design used at Lawrence made no provision for both an AM and a PM estimate of the coliform population on each day.

Similarly, the estimate of the coliform population in a given source sample was calculated from the sum of the logarithms of the two MPN's from that sample. For convenience, the following formula was used to calculate the mean square for differences between duplicate source samples:

$$\frac{\Sigma[(A1 + A2) - (B1 + B2)]^2}{2(2 \text{ MPN's per sample})\ (50 \text{ pairs})} = \frac{11.8000}{200} = 0.0590.$$

The mean square for laboratory duplicates was calculated from the difference between the logarithms of the duplicate MPN's from each source sample—that is, log MPN A1 − log MPN A2, or log MPN B1 − log MPN B2, as indicated in the experimental design in Fig. 1. The following formula was used to calculate the mean square for laboratory duplicates:

$$\frac{\Sigma(A1 - A2)^2 + \Sigma(B1 - B2)^2}{2(50 \text{ pairs A}) + 2(50 \text{ pairs B})} = \frac{9.9400}{200} = 0.0497.$$

Interpretation of Data

Significance of chronologic variation in the coliform population (Column F-Test 1, Table 3). The general practice has been to sample a water supply at specified intervals and to determine only one coliform population index from each sample. Similar estimates were available in this study; however, each AM or PM estimate of the coliform population index for the influent of the Chicago South District Filtration Plant was based on the average of the logarithms of four MPN's—that is, duplicate MPN's for each of duplicate source samples, A and B, as shown in Table 2, Part 3. This was also true for the estimate of the coliform population index obtained for each day in the pond water series at Lawrence.

For convenience in evaluating the average of these logarithms, each based on four individual MPN's, the corresponding F-test based on the analysis of variance is shown in Column F-Test

1, Table 3. In the Chicago series, the day-to-day variation was barely significant at the 5 per cent level when tested against the AM-PM variation. This failure to demonstrate significant chronologic variation, even when using estimates of the coliform population index, based on the averages of logarithms for four replicate MPN's, indicates that still less significance would have been apparent if the usual type of estimation procedure based on only a single MPN per determination had been used.

This confirms the difficulty in detecting moderate changes in the coliform population experienced in standard operating practice. These estimates, based on averages, are less variable than data obtained by the usual procedure of deriving a single MPN per sample. This is true because the standard deviation of a series of averages of four values is only half the size of the corresponding standard deviation based on a similar series of single determinations.

The Lawrence series of data contained estimates of the coliform population on 50 different days. Each estimate was based on the average of four MPN's. The experimental design made no provision for sampling the water supply both in the morning and in the afternoon on each of these 50 days. Therefore, the significance of variation from day to day cannot be tested against the AM-PM variation, which was not determined in this study.

Use of duplicate source samples to obtain added sensitivity (Column F-Test 2, Table 3). Water plants usually collect samples according to some regular schedule—once a day or at specified time intervals. This regularity of routine sampling makes it extremely unlikely that the significance of day-to-day variation would be tested against an error based on variation from samplings within individual days, as shown for the Chicago series in Column F-Test 1, Table 3. Hence, a different standard, independent of the daily trend, but characteristic of the water supply in question, is required. Duplicate source samples provide such a standard.

Consequently, the effect of an error based on MPN's from duplicate source samples was studied. For this purpose, the formal structure of the sampling plan in the Chicago series was ignored. Both the day-to-day and the AM-PM mean squares were considered to be estimates of chronologic fluctuations in the coliform population. The day-to-day variation, however, was not pooled with the AM-PM sum of squares, as a reminder that there may be reason to consider them independently in some future project. The mean square for duplicate source samples was used as the error for testing the significance of both chronologic effects in the Chicago series and of only the day-to-day variation in the Lawrence series. Column F-Test 2 was placed adjacent to Column F-Test 1 to contrast the F-tests. This emphasizes the additional sensitivity obtained in detecting chronologic changes in the coliform population when an error based on MPN's from simultaneous, duplicate water samples was used.

If there is no real chronologic variation in coliform levels, but merely sampling variation characteristic of the water supply at the sampling point, then, in the long run, the F-ratio of the mean square for day-to-day variation divided by the mean square for duplicate source sample variation will be approximately 1.0. Also, the F-ratio of the mean square for AM-PM samples divided by the mean square for duplicate source samples will be ap-

proximately 1.0. If there are definite trends, however, these ratios, or F-values, will be greater than 1.0. They may rise well above the F-value required at the 1 per cent level of significance. This was true of these data, as shown by the tests of significance in Column F-Test 2, Table 3. *It constitutes evidence that the coliform indexes actually do record coliform population changes with greater sensitivity than would be anticipated on the basis of a superficial examination of data consisting of only one MPN per sample and one sample per day.* Here, variation among MPN's from duplicate samples of source water provided one error that was characteristic of the heterogeneity of the coliform distribution in the water from Lake Michigan, and a different error characteristic of a more uniform distribution of coliform organisms in the Lawrence pond. The F-values in Column F-Test 2 afforded the standards for evaluating the significance of the chronologic variation in both series of routine samples, each obtained over a period of several weeks.

TABLE 4

Theoretical and Actual Components of Variance for Chicago and Lawrence Data

Source of Variation	Components of Variation	Mean Square (MS)	Laboratory Duplicates	Source Duplicates	AM-PM	Days
Chicago Series*						
Day to day	theoretical	MS = σ^2_{LD}	+ 2 σ^2_{SD}	+ 4 σ^2_{AM-PM}	+ 8 σ^2_{days}	
	actual	1.6105 = 0.0556	+ 2(0.0424)	+ 4(0.1501)	+ <u>8(0.1087)</u>	
AM-PM	theoretical	MS = σ^2_{LD}	+ 2 σ^2_{SD}	+ 4 σ^2_{AM-PM}		
	actual	0.7410 = 0.0556	+ 2(0.0424)	+ <u>4(0.1501)</u>		
Source duplicates	theoretical	MS = σ^2_{LD}	+ 2σ^2_{SD}			
	actual	0.1405 = 0.0556	+ <u>2(0.0424)</u>			
Laboratory duplicates	theoretical	MS = σ^2_{LD}				
	actual	0.0556 = <u>0.0556</u>				
Lawrence Series*						
Day to day	theoretical	MS = σ^2_{LD}	+ 2 σ^2_{SD}		+ 4 σ^2_{days}	
	actual	1.4867 = 0.0497	+ 2(0.0046)		+ <u>4(0.3569)</u>	
Source duplicates	theoretical	MS = σ^2_{LD}	+ 2 σ^2_{SD}			
	actual	0.0590 = 0.0497	+ <u>2(0.0046)</u>			
Laboratory duplicate	theoretical	MS = σ^2_{LD}				
	actual	0.0497 = <u>0.0497</u>				

* End values are underlined for emphasis.

Variation characteristic of laboratory technique used to study variation among duplicate source samples (Column F-Test 3, Table 3). Finally, an additional standard is required to test the significance of the variance for duplicate source samples. The reproducibility of duplicate MPN's obtained from each source sample provides this

basic standard and also serves as a measure of the quality of the laboratory technique.

The principle of duplicate MPN determinations is acceptable in the laboratory. Additional questions, however, arise regarding the relative value of two MPN's from one sample or one MPN from each of two simultaneous samples. Duplicate MPN's from the same sample are the easiest to prepare. One MPN from each of two independent source samples involves more preparation time and may not appear to constitute "real duplicates" in the sense of two MPN's from the same sample. Actually, sampling and laboratory conditions provide a strong reason for investigating the relationship between the mean square for laboratory duplicates and the mean square for MPN's from source duplicates.

The F-ratio of the mean square for duplicate source samples divided by the mean square for laboratory duplicate MPN's or 2.53, shown for the Chicago study in Column F-Test 3, Table 3, is highly significant, but the corresponding F-value of 1.19 for the Lawrence data is not. Therefore, in the Chicago series, the highly significant mean square for source duplicates (Column F-Test 2) is the appropriate error for testing the significance of the day-to-day variation in the coliform population, as well as the variation in AM-PM samplings of untreated water from Lake Michigan. The exaggerated significance of the day-to-day samplings resulting from the use of the inappropriate error shown in Column F-Test 3, should be carefully noted. In the data from Lawrence, however, the variance for laboratory duplicate MPN's is also the appropriate error variance for testing the significance of chronologic variation in the coliform population. This is true because the F-ratio of 1.19 is not significantly greater than 1.00.

Components of Variance

The experimental designs used for the Chicago and Lawrence investigations were not the same. Therefore, it was necessary to express each analysis of variance in terms of the actual components of variance before attempting to compare the different types of sampling variation recorded by the two laboratories, as shown in Table 4. Only the mean square for laboratory duplicates is also a variance. The remaining mean squares consist of two or more different variance units, or components of variance. The proportions of these components-of-variance units depend on the specific experimental design involved. For example:

$$MS_{\text{day-to-day}} = \sigma^2_{LD} + 2(\sigma^2_{SD}) + 4(\sigma^2_{AM\text{-}PM}) + 8(\sigma^2_{days})$$

or, for the Chicago series:

$$1.6105 = 0.0556 + 2(0.0424) + 4(0.1501) + 8(0.1087).$$

MS is the mean square; σ^2, the variance; LD, laboratory duplicates; SD, source duplicates; and AM-PM, forenoon-afternoon.

In addition to facilitating comparison of variances obtained from different experimental designs, these components of variance are useful for estimating the mean squares to be expected if other experimental designs are used. Table 5 illustrates the use of components of variance to provide insight regarding the interpretation of a single standard deviation calculated from a series of MPN's when one MPN is derived from a single water sample, each collected on a different day. The single MPN each day does

not provide a means of distinguishing the variation among MPN's associated with day-to-day samples, AM-PM samples, source duplicate samples, and laboratory duplicate samples. This is true in spite of the fact that each of these four sources of variation actually contributes to the total variation among the series of single MPN's obtained at the rate of one sample per day.

The components of variance from the two respective projects were totaled in Table 5 to estimate the mean square that would have been obtained had only one MPN per day been available under these conditions. Estimated mean squares of 0.3568 and 0.4112 were obtained for Lake Michigan water and pond water at Lawrence, respectively. The corresponding standard deviations are the square roots of these totals.

It is obvious from Table 5 and the previous discussion of the analysis of variance that these estimated standard deviations do not form a rational basis for comparing the quality of the work in the two laboratories. The only directly comparable measures of the quality of the laboratory technique are the variances for laboratory duplicates (0.0556 and 0.0497). The remaining components of variance are measures of variation characteristic of each water supply and, as such, are independent of the quality of bacteriologic work carried out in the two laboratories.

TABLE 5

Components of Variance, Taken From Table 4

Source of Variation	Estimated Mean Square	
	Lake Michigan Water	Pond Water at Lawrence
Day to day	0.1087	0.3569
AM-PM	0.1501	
Source duplicates	0.0424	0.0046
Laboratory duplicates	0.0556	0.0497
Total	0.3568	0.4112
Estimated standard deviation	0.5973	0.6412

General Discussion

The usual practice of obtaining one MPN from one sample, each day from a specific water supply, frequently results in a characteristic variation among the MPN's. The variation for similar series of MPN's from two different water supplies may differ widely, yet may be remarkably consistent for a series of MPN's from the same supply. The usual laboratory procedures provide no way of explaining these differences. When components of variance are available, however, as in this study, such an explanation can be constructed. These components may be combined to estimate the variance obtained under the usual sampling conditions. Chronologic variation in the coliform population, variation due to nonuniform distributions of coliform bacteria in the water at the sampling point, and variation characteristic of the quality of the laboratory technique can be separated and examined.

A single MPN prepared from each of duplicate source samples would provide no way of distinguishing variation due to a heterogeneous coliform distribution in the water supply from the variation associated with the quality of laboratory technique used to prepare the MPN tests. The only directly comparable measures of the laboratory technique in this study are the variances for laboratory duplicates—0.0556 (Chicago) and 0.0497 (Lawrence). Both laboratories followed the

same procedure of mixing each primary water sample (A or B) and each subsample (A1 or A2, B1 or B2) by shaking 25 times. Aliquots for one set of MPN tubes were planted promptly from each subsample. As both laboratories followed the same procedure, similar variances were to be expected for duplicate MPN's from the same sample.

The component of variance for source duplicates of 0.0046 for Lawrence indicated a homogeneous distribution of coliform organisms in the relatively quiet pond water. The corresponding component of 0.0424 reflected a more heterogeneous mixture of polluted and less polluted water, created by the more turbulent action along the shores of Lake Michigan.

Definite experimental evidence is required before coliform bacteria can be assumed to have been distributed uniformly throughout a water supply. Forces producing turbulence, in the absence of counteracting elements, act irregularly to mix polluted water with unpolluted water. Hydrologic factors associated with a large body of water are numerous and complex, therefore hard to evaluate. On the other hand, for a small body of water like Searles Pond near Lawrence, Mass., these factors can be more accurately estimated. The consequent mixture in a given period would be expected to be more heterogeneous in a body of water as large and turbulent as Lake Michigan than in Searles Pond, other things being equal. Field observations of raw sewage in rivers and large lakes often suggest that the mixing process may proceed slowly. The larger component of variance for duplicate source samples from Lake Michigan (0.0424) and the smaller one (0.0046) for the Lawrence pond appear to confirm this expected distribution of coliform organisms in the two water supplies.

The size of the components of variance measuring chronologic variation also appeared to confirm the variation in coliform density to be expected from the relative sizes of the two bodies of water. Extreme chronologic fluctuations in coliform density of the Lake Michigan samples were not anticipated. At Lake Michigan, the polluted shoreline water is constantly being diluted by more nearly potable water from deeper areas of the lake. The components of variance for the chronologic variation—day to day, 0.1087, and AM-PM, 0.1501—were smaller than the corresponding value of 0.3569 for day-to-day variation at Lawrence.

The components of variance discussed above provide a means of interpreting the estimated standard deviation for a series of one MPN from one sample per day calculated from the Lake Michigan data (0.5973) and from Lawrence (0.6412), shown in Table 5. Although the standard deviation values are similar, the size of individual components of variance appears to correspond to known characteristics of the two water supplies under investigation.

In this study, the close agreement between the variances for laboratory duplicates in both laboratories demonstrates a valid basis for interlaboratory comparisons. Experiments designed to include measures of this variation will provide a useful basis for comparing the quality of work done in branch laboratories under the direction of a central laboratory, or in coordinated studies carried out by a group of independent laboratories.

Conclusions

Without confirmatory evidence, the variation commonly observed in a

series of MPN data, obtained by preparing one MPN from one sample each day, should not be attributed largely to laboratory technique, or considered to be inherent in the multitube fermentation procedure itself.

Data obtained in accordance with a simple experimental design and subjected to analysis of variance procedures made it possible to measure and to study variation within a series of MPN values associated with:

1. Day-to-day chronologic fluctuation in coliform density in untreated Lake Michigan water at the Chicago South District Filtration Plant and in samples of pond water at Lawrence, Mass.

2. Differences in coliform levels between samples obtained in the forenoon and in the afternoon of the same day, at Chicago only

3. Differences between duplicate samples from specific water supplies

4. Differences between duplicate five-tube, decimal dilution MPN's prepared from the same water sample.

The difference between duplicate MPN's prepared from the same sample is a measure of the quality of the bacteriologic technique used in a given laboratory. These differences can also be used to compare the quality of work in several laboratories following the same standard laboratory procedure. This was confirmed experimentally by the standard deviation of 0.2358 obtained for differences between duplicate MPN's from 100 samples of untreated Lake Michigan water, and a corresponding standard deviation of 0.2230 from 100 samples of pond water at Lawrence. All MPN's were converted to logarithms to the base 10 before statistical analysis.

The characteristic reproducibility of duplicate MPN's prepared from the same water sample provides a standard for evaluating the significance of differences in the coliform populations obtained in a series of water samples. Both the Lake Michigan and Lawrence series of tests showed highly significant day-to-day fluctuations in the coliform population. Duplicate water samples, however, showed that the coliform bacteria were distributed more uniformly in the Lawrence pond water than in the Lake Michigan water.

Acknowledgment

This study was made possible through the cooperation of John R. Baylis, Oscar Gullans, and James C. Vaughn, all of the Chicago South District Filtration Plant. The study is also part of a project carried out in cooperation with L. R. Hedrick, chairman, and Marjorie L. Sutherland, biostatistician, both of the Department of Biology, Illinois Institute of Technology, Chicago, Ill.

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2. Snedecor, G. W. *Statistical Methods.* Iowa State College Press, Ames, Iowa (4th ed., 1946).
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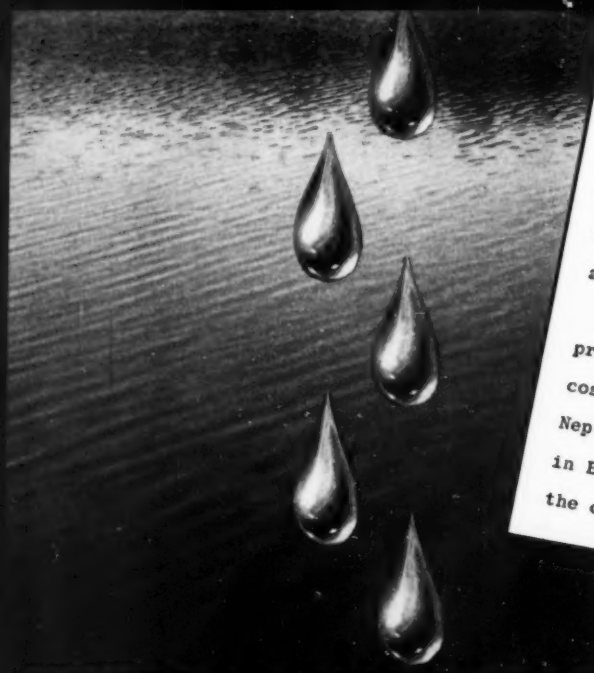

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To help point out the problems of conservation and cost you share with industry, Neptune is placing this message in Business Week before the the country's business leaders.

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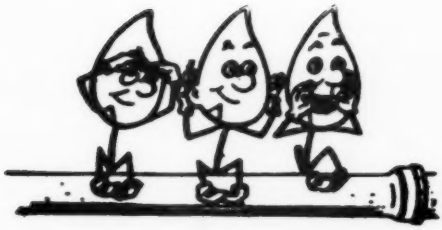

Percolation and Runoff

Bal Harbour? Where is that? Or, more to the point, when is that? And as our is is your was, Bal Harbour can't be *here* until next month. Which is merely to point out that the lack of coverage stems not from ignor'ance, but ig'norance.

Cleary, Biery be the names of the heroes of "The New Ohio," a river on which boating is now booming, sportsmen get occasional bass strikes, and even swimming is coming back. Actually, Biery—Hudson Biery (who should certainly change his first name)—came first, back in the early 1930's, when the river was practically pure sewer. A pressagent who adopted the river as a charity client, Biery enlisted the aid of the Cincinnati *Enquirer* and the Cincinnati Chamber of Commerce in a cleanup campaign, a campaign which aroused the people with such homey thoughts as: "We in Cincinnati can always tell when people in Pittsburgh have had asparagus for dinner." By 1936 the campaign had stirred Congress to pass a resolution making the eight-state Ohio River Valley Water Sanitation Commission possible. It wasn't until after the war—in 1948—that Orsanco finally got under way, but then Cleary—Edward J. Cleary—as executive director and chief engineer, took over the job of education and persuasion in a drive to get 1,000 basin towns and cities and 1,443 industrial plants to clean up their wastes before discharging them into the river. By now, it is reported in no less media than *Time* (Jan. 11, 1960) and *Business Week* (Mar. 5, 1960), that the sewage of 95 per cent of the riverside population and of 82 per cent of the total population is being, or will soon be, at least partially treated and that 80 per cent of the industrial plants are doing at least a minimum job of waste control. And if the Ohio is not yet the "thing of beauty" its name means, it is at least a river again and headed in the right direction through and through the cooperation of eight states—Biery-bearded, Cleary-cleared!

'Soakers Soaked' could have been the headline in the Buffalo papers last Mar. 28 when a main break poured "tons of water" through the basement offices of the Internal Revenue Service. Had it happened 3 weeks later . . . but, oh well, the tax records were only damaged. A good drying out, apparently, is all the offices and records need to get back to soaking again.

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EauNeill it surely is instead of O'Neill, for the O'Neills have meant "water" to Lake Geneva, Wis., for a total of 255 years, man and boy, sister and brother. Actually it was 1890 when the first O'Neill —William Sr.— built the first water system for Lake Geneva and then took over as its chief. He remained on the job for 37 years and, upon his death, son Christopher took over the reins. And when Christopher retired on May 1, 1958, having completed 50 years of service with the utility, there was assistant superintendent Joseph H. O'Neill with 39 years of service and Eugene A. O'Neill, with 35, and third generation William O'Neill Jr., with 10, to carry on operations, not to mention bookkeeper Molly O'Neill Shicke, who had presided over the office for 47 years. It was when Christopher O'Neill became a Life Member of AWWA in February that the story of the long *eau* in O'Neill came out. We salute him again and all the EauNeills!

Warehouse inventories maintained by water and sewerage utilities are the subject of a survey sponsored jointly by BDSA and USPHS. During the next month the Bureau of the Census will mail questionnaires to managements of all publicly owned water and sewerage utilities serving populations greater than 5,000 and to the privately owned water utilities serving populations of 25,000 or more. A total of nearly 3,000 water and 2,500 sewerage utilities will be included in the survey. The questionnaire will request information on the working and reserve stocks of materials and equipment kept by the utilities. These data will then be correlated by the Office of Civil and Defense Mobilization with similar data on availability from other sources. The accumulated data will finally be evaluated to determine total stocks of critical materials and equipment, and to estimate requirements for essential materials in the event of a nuclear attack or other major disaster. This activity is a part of the broad survival-items program being coordinated by the OCDM. The data will be made available to authorized agencies from the OCDM.

The survey of essential materials is a part of the program of the OCDM to assess the civil defense and mobilization readiness of essential services such as water and sewerage utilities. These determinations will assist in the planning to meet disaster conditions at state and local, as well as federal, levels.

The OCDM considers that planning to assure safe and adequate water supplies for the surviving population must receive a high priority to prepare for survival and maintenance of health in the event of a nuclear attack. AWWA members are requested to give active and full cooperation to effect complete and early return of the data requested.

E. A. Savinelli has been appointed research director for the Power Chemicals Div., E. F. Drew & Co., where he will be responsible for development of new water treatment chemicals and processes. Formerly a consultant with the du Pont Co., he will be located at the Boonton, N.J., research laboratory.

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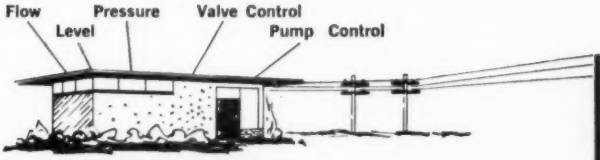
FLUIDICS* AT WORK



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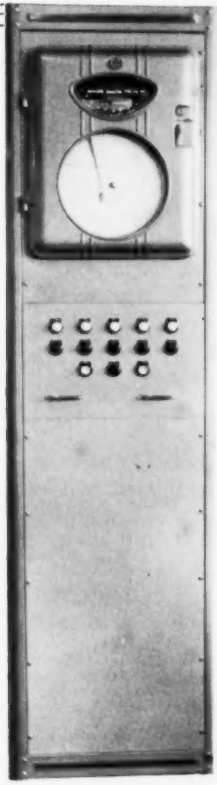

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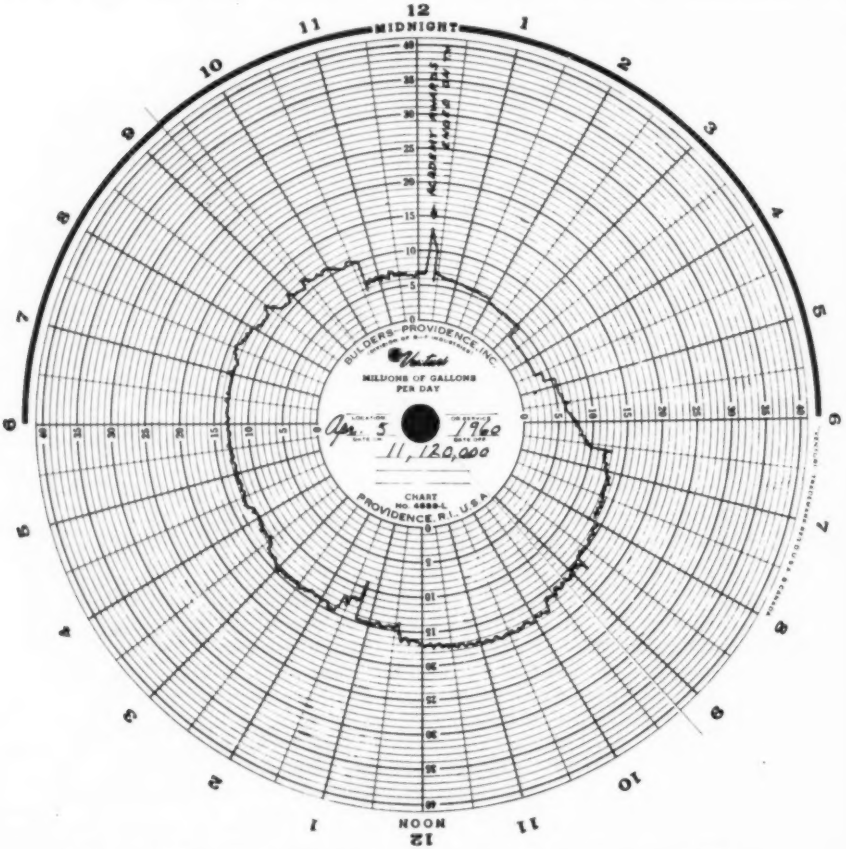
(Continued from page 46 P&R)

The Teleflush Index, whereby the popularity of television programs is expressed in terms of mid- or post-program water demand, received further acclaim recently following its demonstration on Apr. 5 at Stamford, Conn. It was the Academy Award presentation program that put the index to test and found it passing with flowing colors—a 6-mgd surge in demand at 12:15 AM (see chart) accurately reflecting the record number of viewers involved.

The reliability of water use as a measure of pleasure, not to mention comfort, is no great surprise to us, but the fact that it usually is to the public ought to be a source of publicity, if not profit. In other words, if water utilities are unsuccessful in selling the index service to TV broadcasters, they can certainly provide the information as



That peaking, not peeking, is the secret of the Stamford Water Co.'s measure of local televiewing is demonstrated by this venturi record of water use on the evening of the Academy Award show.

(Continued on page 50 P&R)

BRINE PIPING

How it can affect design of water softening installations

Delivering brine when and where it's needed depends on several important requirements. For instance, the piping must have adequate capacity . . . fittings and valves should resist corrosion . . . and pumps should be correctly located. With the ever-growing amounts of brine called for in today's water softening installations, it's also important to provide for economical expansion of existing piping layouts as needed.

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news to the local press and thereby keep water supply in the public eye—even as a public eye.

Whither weather is a considerable question these days—one not only of prediction, but of prescription, as the tools and techniques of both forecasting and modification are constantly being improved. The Weather Bureau, for instance, is sponsoring extensive research on further development of radar techniques and on improved classification and interpretation of radar information. Another tool—electronic data-processing equipment—has already made possible the correlation of past weather records on a scale heretofore unimaginable and has only begun to demonstrate its value in weather research and analysis. Meanwhile, the establishment of satellite observation points in space permits meteorologists to reach out still further toward understanding weather phenomena—an understanding that is necessary to both prediction and prescription.

On the prediction front, the Weather Bureau, stimulated by the findings of the International Geophysical Year, has been extending the range and accuracy of its forecasts. At the Smithsonian Institution, Dr. Charles G. Abbott, an expert in solar research, recently issued precipitation predictions through 1967 for 32 US cities, forecasting monthly totals and 4-month averages. In Paris, explorer Paul-Emile Victor indicated that it would soon be possible to foretell the weather years in advance

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through the study of Greenland and Antarctic ice. And on a commercial scale, Irving P. Krick & Assocs., weather consultants of Denver, have been developing and electronically correlating their own weather data and selling a long-range forecasting service to utilities, industrial concerns, municipalities, farm groups, and others to whom foreknowledge of what to expect weatherwise can be profitable. As meteorologist on Eisenhower's staff during World War II, Krick helped pick D-day; as consultant to the 1960 Winter Olympics Committee, he, 3 years ago, picked the dates for the Squaw Valley snow meet; and now on a regular basis he is alerting power utilities as to when they will need to augment their water power facilities,

(Continued on page 52 P&R)

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(Continued from page 51 P&R)

telling oil companies and soft-drink bottlers when they must be ready to meet the greatest demands, warning cities when they should have their snow removal equipment and personnel ready, giving farmers the word on when to plant and when to harvest, and just generally telling people when to get off.

On the prescription front, meanwhile, the same Dr. Krick is busy, through his Water Resources Development Corp., seeding clouds the world over to help increase precipitation where more water is wanted. In this activity, too, utilities and municipalities are among his best customers. And it is no secret that the snow which arrived at Squaw Valley just in time had the help of Dr. Krick's silver iodide whether it needed it or not. As far as the prescription of weather is concerned, most scientists feel that the methods for control are either on hand or within reach. What is causing concern are the possible side effects of weather control. As Prof. S. G. Davis of Hong Kong University recently pointed out, "The Russians know how to do it [through melting snow by nuclear fission] and it may be in the near future that Russia will have no winter. However, drastic changes could be more dangerous to the world than all the nuclear weapons invented." Not only would such changes set up pressure areas that would thrash the world about with continual typhoons, but they could trigger the melting of the polar icecaps and thereby inundate a considerable portion of our present

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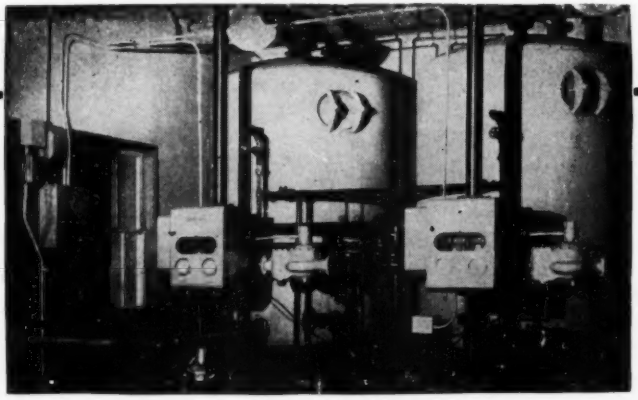

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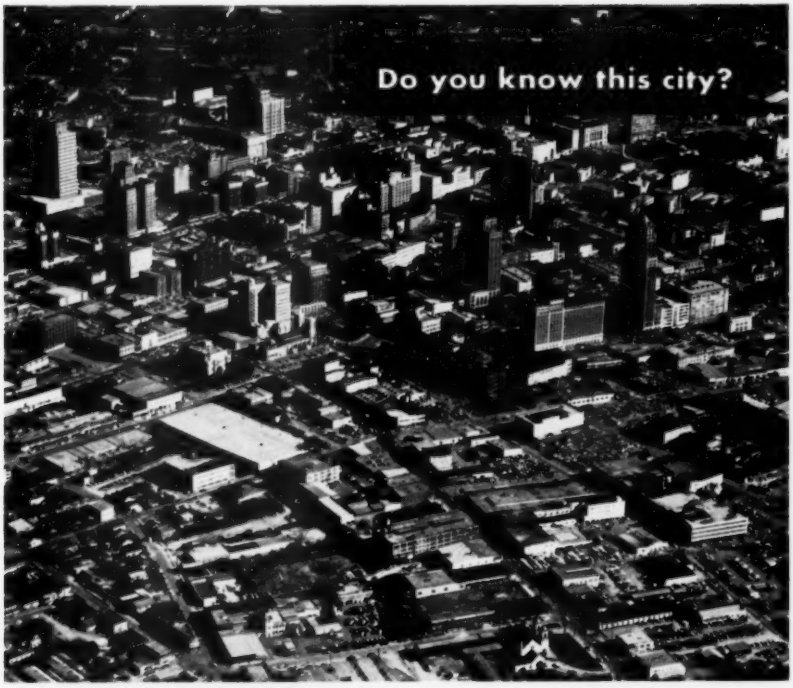

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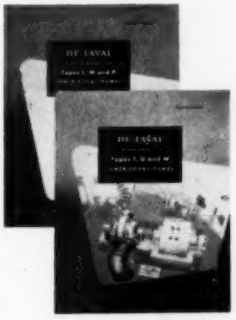

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(Continued from page 52 P&R)

land area. On the sidelines some of our military experts are considerably concerned about the use of weather as a weapon—not only to starve an enemy by killing his crops, and to hamper his movement through mud, but to dampen his spirit with continual rain. And, in Cleveland, the police department is now busy investigating the possibility that rain increases crime and is requiring its investigating officers to add to their reports information on temperatures, wind velocity and direction, and precipitation.

Next thing you know everybody will be doing something about the weather and nobody will be talking about it.

Taps for 'taps' is what the Plumbing-Heating-Cooling Information Bureau of Chicago has been blowing. Call them "faucets," the bureau says, not "taps." "Tap," it seems, may be satisfactory as a term for "an old leaking lavatory or kitchen sink fixture that has seen years of use and abuse, but it does not do justice to the beauty and functional design of the modern faucet," for which "bathroom jewelry" is deemed more appropriate. "The better quality faucet available today," according to the bureau, "is the result of expert craftsmanship and artistic design. . . . It is a fine piece of precision engineering made for easy cleaning and long, satisfactory service. All moving parts are easily renewable." In fact, for no more than $7 or $8 one can have a washer replaced—that is, if one doesn't first try to replace it himself

(Continued on page 56 P&R)

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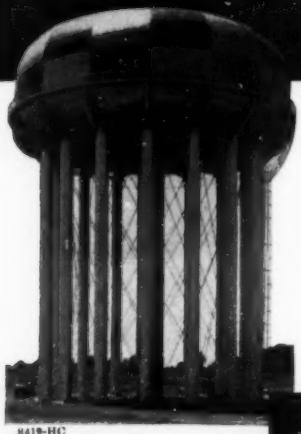

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(Continued from page 54 P&R)

and get tangled up in some of the precision. Even then, the cost will usually not exceed $15, and the nuisance of washing in the kitchen for a week or so is really a small price for all that beauty.

The real point, though, is that, even if we hadn't just paid another faucet engineering fee, we would prefer "tap" to "faucet." There is something dissonant about "faucet," something backyardish that nullifies the bureau's entire argument. Accepting, if not understanding, the distaste for "tap," we would certainly urge some better substitute—not "spigot" either, nor, indeed, "cock." As a matter of fact, pressed for a suitable alternative, we would have to go back to antiquity and resurrect the English term, "dossil," as being the one properly euphonious and adequately dignified term to "do justice" to the expensive jewelry of the modern W.C. Of course, we would not overlook the fact that dossil water is just what it sounds to be—agreeable, tractable!

And we're not blaming the plumbers either; it's those damned dossil designers.

Red water is actually being sought by Hong Kong, where less than 4 in. of rain has fallen since last October, compared with a normal 8 in., and where the refugee-swollen population has reached a thirsty total of 3,000,000. In mid-April, the governor of the British colony entered into negotiations

(Continued on page 58 P&R)

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(Continued from page 56 P&R)

with the Chinese Communists seeking to tap their new reservoir at Shumchun, 30 mi from the island. And as the red is political rather than ferrous, it should not spoil the water, for water and politics, we know from long experience, do not mix.

Problems, problems, problems—not just the old, impossible ones that never go away, but always something new, too!

At Mt. Sterling, Ky., for instance, someone messed up a meter installation 14 years ago and ever since a hardware store has been paying the water bills of a neighboring supply firm. It didn't even help much to learn that the supply firm had been paying the hardware store's electric bill for 15 years because of a similar mixup in electric meters.

At Baltimore, Md., one night a man fell into an open manhole as he approached his parked car. He managed to walk to a police station for help and was taken to a hospital. Meanwhile, a patrolman sent out to investigate fell into another manhole and also had to be taken to the hospital. Not an employee oversight, fortunately, but the work of someone who apparently felt that manholes were for men, for the covers were located on the other side of a nearby fence.

At Charlotte, N.C., firemen rushed out to answer a call, hooked their hoses to a couple of hydrants, aimed their

(Continued on page 62 P&R)

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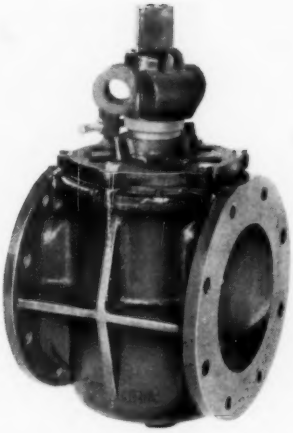

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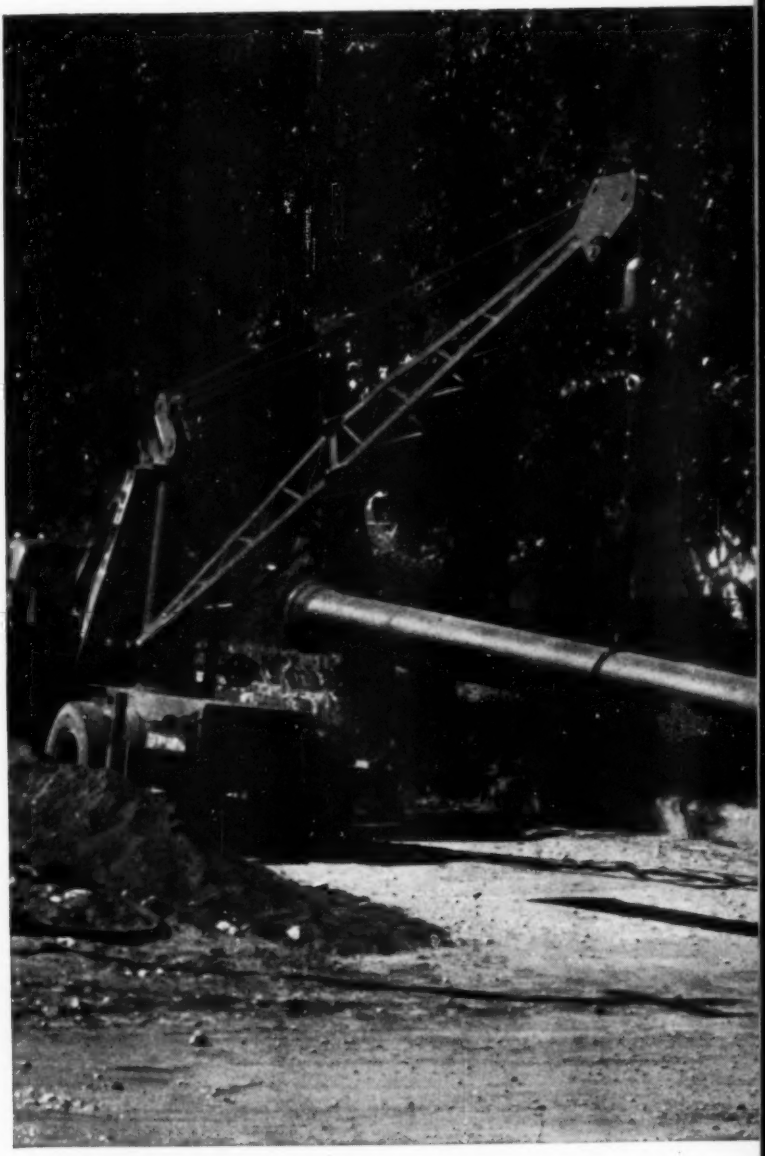

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(Continued from page 58 P&R)

nozzles at a burning garage, and found that the hydrants had not yet been connected to the water mains. It may have been comforting to learn that the building, in a newly annexed area, would probably have burned to the ground even if there had been water.

At Columbia, Mo., the night operator at the water and light department dropped off for a snooze one morning. The steam in the boilers went down, the electric power went off, the heat in local homes cut off in the 15°F cold, but the utility manager managed to keep hot, particularly under the collar.

At Milwaukee, Wis., firemen found themselves on the guessing end of a hide-and-seek game, when snowplows buried many of the city's hydrants and they forgot where they had seen them last. Officials had to issue an emergency call for citizen help in locating the hidden plugs.

At Raleigh, N.C., though, when a man swallowed the handle of a water faucet, it was not the water department which was called upon. Perhaps that was because the trouble was on the customer's side of the meter, but more likely because the customer was the Central Prison and because the ingurgitation took place in an isolation cell.

Next month, East Lynn!

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Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

SOFTENING AND IRON REMOVAL

Iron Removal Plant at Vedrin-Saint-Marc. R. Buydens. *Tech. l'Eau* (Brussels), 2:130:15 ('57). The Vedrin-Saint-Marc plant is equipped to realize complete treatment of water issued from pyrite mines. Prefiltration at 8–10 mph is advantageously used instead of prelim. ventilation. A 2nd filtration is used afterwards at 5 mph. The total vol. of water to be treated is 40,000 cu m/day, the prefilter and filter surfaces are, resp., 240 and 480 sq m. The filters are made of calibrated sand (1–2 mm). The water contains 5.6 mg Fe, with 4.1 mg as Fe^{++}. The prefiltration removes 94% of both Fe^{+++} and Fe^{++} ions. Electroneg. SiO_2 grains retain the electropos. Fe colloidal micelles. Sludge analysis shows an important $CaCO_3$ retention. Filter washing is described. Recovery of wash water consists of decantation followed by chem. treatment: $FeCl_3$ addn. and stirring (10 min) start flocculation.—*CA*

Introductory Notes for the Study of Ion-Exchange Materials. R. Rayet. *Bul. Mens. Centre Belge Etude Document. Eaux* (Liege), 87:79 ('58). The author gives the terms used in connection with ion exchange, with the corresponding Dutch, English and German expressions, defines the special units of measurement employed and gives tables showing the relations between units used in different countries.—*WPA*

Ion-Exchange Applied to the Drinking-Water Softening at Tournai (Belgium). L. Laude. *Tech. l'eau* (Brussels), 12:135:15 ('58). The O.C.P. process (Brussels) has been advantageously adopted. Sulfonated polystyrene cation-exchanger (Lewatit S 100) has showed an excellent phys. and chem. resistance. The plant includes 3 open filters (section 10 sq m), each contg. 10,000 l resin. The exchanger lies on filtering flagstones, and draining is effected underneath by pipes. The treatment process is the following: (a) impurities removal, (b) compd. regeneration by passage first of recuperated brine then of fresh brine with recuperation of the effluent, (c) double rinsing, (d) start up. Several numerical values make the performance clear.—*CA*

Ion Exchange in Water Treatment. R. G. Tredgett. *Munic. Utilities Mag.*, 96:7:56 ('58). The author describes various applications of ion-exchange process for treatment of municipal and industrial water supplies. In the municipal field, ion exchange is used primarily in the softening of hard waters and in the removal of iron present in raw-water supplies. It is also widely applied in the industrial field where the requirements of boiler feed and process waters are exceedingly rigid.—*WPA*

Observations on the Variations in Concentration of Manganese in Reservoirs. H. Guignard. *Eau* (Fr.), 44:143 ('57). Although manganese often occurs in high concns. in water in reservoirs, generally in association with iron, the need for removing it from the water is frequently overlooked, since manganese, although present in slightly higher concns., gives very similar color and pptn. reactions to iron, forms a deposit of oxide very similar to, though darker in color than, that produced by iron, and induces the growth of *Crenothrix* and *Leptothrix* bacteria, which block water mains and pipes with their growth, and which are also found in the presence of iron alone. In water, manganese occurs mainly in the form of bicarbonates, sulfates, and chlorides, and in organic compds. such as humates. There are several methods of water treatment for the removal of manganese, which involve oxidation, agitation to facilitate the formation of a ppt., and filtration. The methods differ only

(*Continued on page 74 P&R*)

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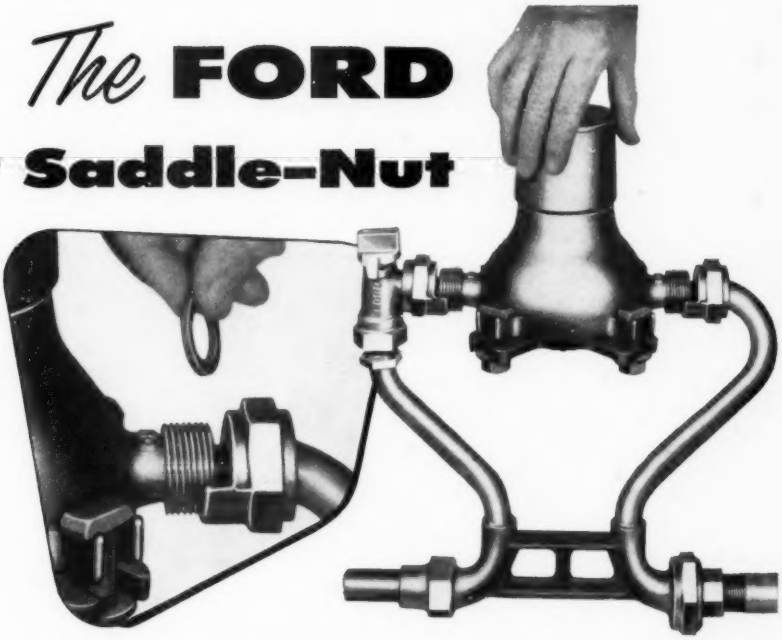

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(Continued from page 72 P&R)

in the means of oxidation, and in the pH value at which oxidation is carried out. Agitation, and the simultaneous pptn. of iron, accelerate the reaction. Oxidation may be carried out by aeration under pressure, or by contact aeration together with a simultaneous raising of the pH value, or occasionally by potassium permanganate. Examples of the treatment of manganiferous waters at coal mines in the Lorraine Basin, from the Eupen and Angle Guignard reservoirs, and from lake Abbaye, are described. In conclusion, it is stated that prelim. treatment is sometimes required owing to the seasonal occurrence of microorganisms, mainly bacteria and protozoa, which can sequester manganese in a form which is not affected by the usual methods of treatment.—*WPA*

CORROSION

Cathodic Protection of Lead Cable Sheath. W. H. BRUCKNER & O. G. JANSSON. *Corrosion*, 15:67 ('59). By observation of the corrosion limit and the corresponding potential, it is possible to define the cathodic-protection requirements for permanence of metallic Pb as a function of the pH of the environment. Overprotection and soil barrier diffusion increase the susceptibility to corrosion during periods of min. current supply. The Pb electrode was found to be unsatisfactory for measuring static potentials in the field.—*IM*

Prevention of Corrosion and Mineral Deposit Formation in the Pipes of Turbine Condensers. D. E. KRASNOZHEN ET AL. *Elek. Stantsii* (USSR), 30:7:29 ('59). Processing cooling water by means of exhaust gases (recarbonization) effectively prevents the formation of mineral deposits in condenser coils of turbines. The main advantage of this method is its low cost; its main disadvantage is an increased rate of corrosion of the piping as a result of a greater concn. of CO_2 in the water. Ordinary brass (L-68 or L-62) is very corrosion prone if the water has a high mineral content. Its loss of Zn is very rapid irrespective of the

(Continued on page 76 P&R)

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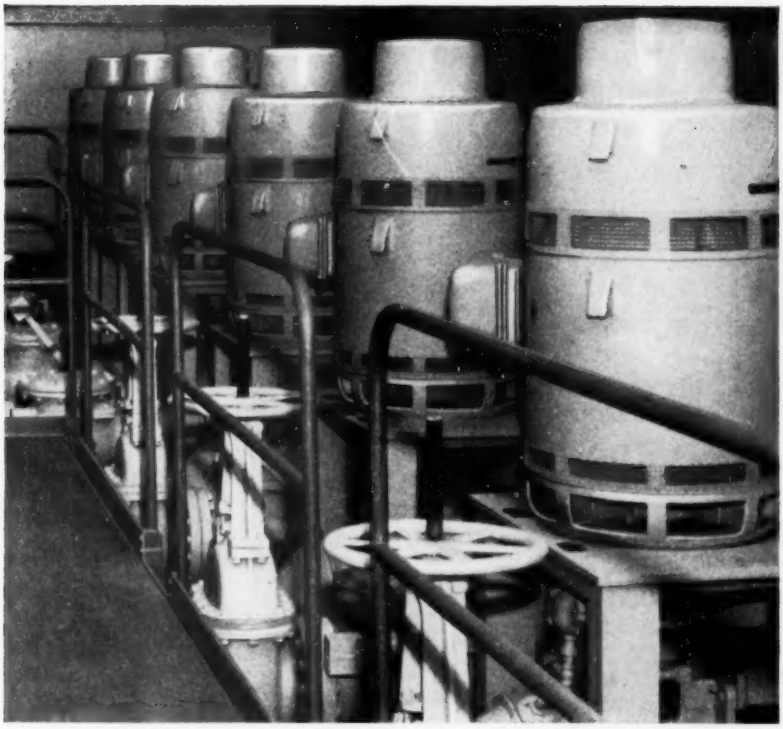

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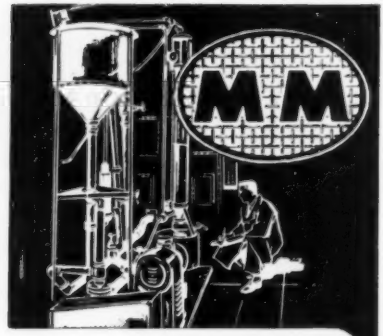

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(Continued from page 74 P&R)

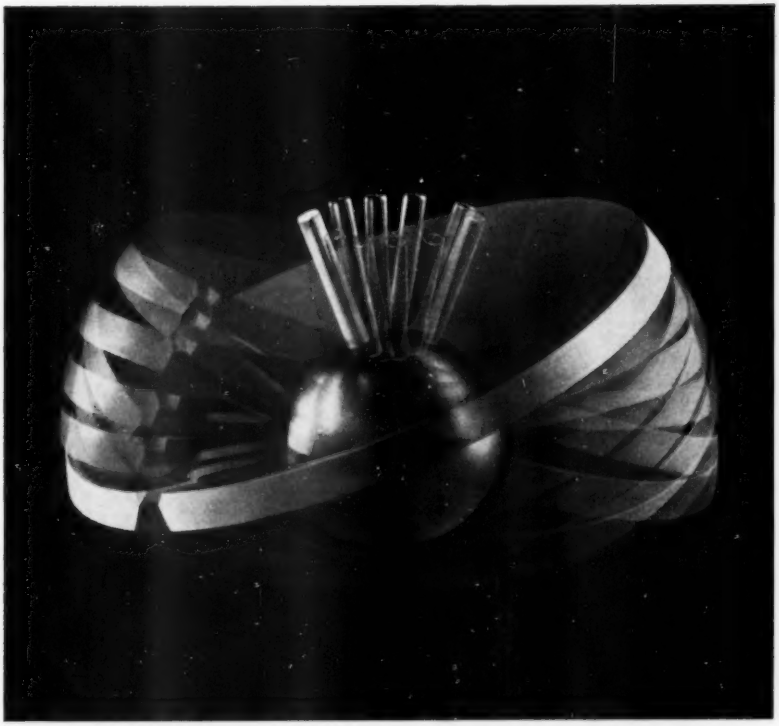
treatment given to the cooling water. Sn-contg. brass (LO-70-1), red copper, and melchior resist corrosion better when the cooling water is phosphated and acidified than when it is "recarbonized." The high CO_2 content of recarbonized water (10–12 mg/l) reduces the corrosion resistance of melchior 10–20 fold, whereas that of brass (LO-70-1) and of red copper is affected only slightly (50–100% reduction). Of the metals tested, red copper was found to be the most resistant to corrosion under conditions where the cooling water is recarbonized. The rate of corrosion of red Cu decreases with time. The properties of brass (LO-70-1) are very similar but a choice between the 2 metals should be dictated by the rate of flow of the H_2O in the pipes (1.5 m/sec for red Cu, 1.5 m/sec for brass). The rate of corrosion of melchior in recarbonized water is identical with that of red Cu; however, it does not decrease with time. Thus, under the above conditions no advantage is to be gained from using the more expensive melchior. The metal in the pipe has a strong influence on the amt. of minerals deposited within the pipe, red copper being the best in this respect.—*CA*

The Action of Metallic Zinc in Paints. H. J. SCHUSTER. *Werkstoffe u. Korrosion* (Ger.), 10:490 ('59). Electrochem. action of Zn protection on Fe is explained by means of current voltage diagrams. It is shown that Zn powder in a paint first protects electrochem., then pores are filled by insoluble basic Zn compds. which suspend the action, and finally scaling takes place by air oxidation. Zn paints are seen as different from, and not as substitutes for, galvanizing.—*IM*

Possibilities of Zinc in the Fight Against Marine Corrosion. R. SOUSKE. *Corrosion et Anti-corrosion* (Fr.), 7:356 ('59). Protection of steel by Zn anodes and by Zn plating, spraying, diffusion, and painting is reviewed. Salt spray test results showing the effects of temp. and Zn purity in hot galvanizing are illustrated.—*IM*

Rust Prevention—Sprayed Metal Coatings. HANS REININGER. *Werkstoffe u. Korrosion*, (Ger.), 10:477 ('59). Examples of protective coatings are given, including metal spray paint treatments. Magnetic and inductive

(Continued on page 80 P&R)



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(Continued from page 76 P&R)

coating thickness meters are described. Metal usage unit surface varies with the type of surface sprayed. Statistical variation of spray coat thickness is shown and the importance of good spray technique is emphasized.—*IM*

On the Corrosion of Metals in Salt Water. Y. AOYAMA. *Naturwiss.* (Ger.), 46:107 ('59). Pure Mg powder was immersed for 3 months in 0.1*N* KCl soln. The corrosion product was heated in water to form crystals. X-ray diffraction showed the product to be basic $MgCl_2$. It is concluded that the formation of a basic salt is the cause of the rapid corrosion of Mg—and probably of other metals—in salt water.—*IM*

The Formation of Porous Oxides on Metals. D. N. AYLMORE; S. J. GREGG; & W. P. JEPSON. *J. Electrochem. Soc.*, 106: 1010 ('59). Measurements of the sp. surface and *d* indicate that oxides on Co, Ce, Pb, Mg, Nb, Th, W, and U are porous to mol. O. The rate of oxidn. of these metals is governed by the diffusion of O across a thin barrier film of oxide. The parabolic oxidn. of Co and Cu is explained by the assumption that oxide films are nonporous to gaseous O. The results suggest that the films on Co and Cu are largely nonporous.—*IM*

Oxidation of Metals—The General Oxidation Equation. TOR HURLEN. *Acta Chem. Scand.* (Den.), 13:695 ('59). From the abs. reaction rate theory, a general oxidn. equation is stated for transport of metal and oxide vacancies and interstitials in ideal soln. in the oxide film, under the action of chem. and elec.-potential fields. This is manipulated to give inverse-log., cubic, and parabolic oxidn. equations, and the assumptions made for this purpose lead to the association of a range of film thicknesses with each type of equation, such that a complete oxidn. time observation embraces an initial period of inverse-log. oxidn. and changes smoothly to a period of cubic and general oxidn. and, finally, parabolic oxidn. The regions of validity of each rate equation are calcd. for Ti oxidized to TiO_2, and presented graphi-

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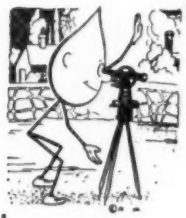

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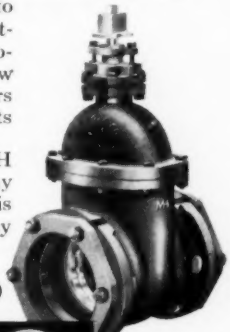

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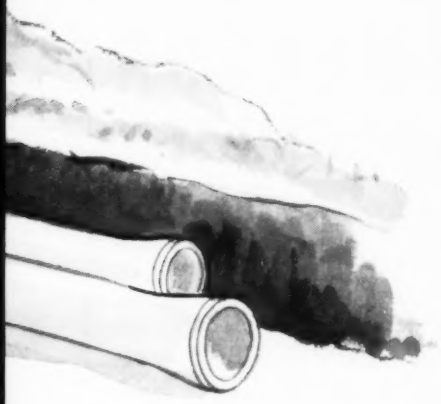

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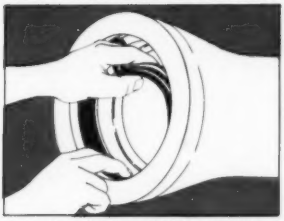

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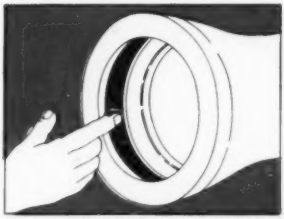

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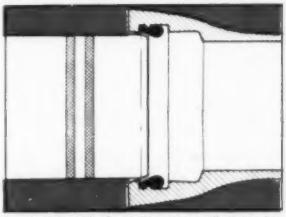
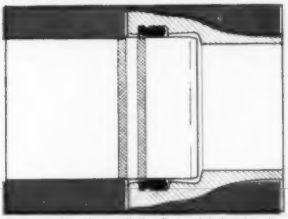


Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . . fast, efficiently, economically. Could anything be simpler?

(*Continued from page 80 P&R*)

cally in terms of film thickness at the oxidn. temp. The conditions for cubic oxidn. do not require the assumption of a *p*-type oxide. —*IM*

Corrosion of Aluminium Alloy in Glycol–Water Cooling Systems. N. S. DEMPSTER. *Corrosion*, 15:13 ('59). Al alloy is very sensitive to corrosion in a 30:70 glycol–water mixture contg. ~0.3–2 ppm Cu in soln. and 10–15 ppm chloride. Two inhibitive systems were found satisfactory: Na tetrasilicate + Na tetraborate and the same + Na cinnamate.—*IM*

Corrosion Resistance of Lead-Silicon and Lead-Antimony-Silicon Alloys. MASAO TERASAWA. *Nippon Kinzoku Gakkai-Si* (Jap.), 23:194 ('59). Flash tests on these alloys were made in H_2SO_4, HCl, and $(NH_4)_2SO_4$ soln. The corrosion resistance, **I**, was lower for Pb-Si alloys than for Pb; Pb-Sb alloys had lower **I** than had Pb and Pb-Sb-Si alloys. The corrosion rate, **II**, of Pb-Si alloys was markedly affected by Si content in the range 0.008–0.017% Si independently of concn. and temp. of acid soln.: in H_2SO_4 **I** improved generally, and in HCl **I** increased in proportion to Si content. In $(NH_4)_2SO_4$ soln. **I** was unchanged by Si content. **II** of Pb-Sb-Si alloys changed considerably with Si content up to 1%. In H_2SO_4 at 30 and 75°C, Pb-Sb-Si alloys had higher **I** than had Pb-Sb alloys, and in HCl and $(NH_4)_2SO_4$ soln., **I** of the ternary alloys increased in proportion to the Sb content.—*IM*

Galvanic Relationships Between Aluminium Alloys and Magnesium Alloys—Galvanic Couples and Aluminium Claddings on Magnesium. M. R. BOTHWELL. *J. Electrochem. Soc.*, 106:1014 ('59). High-purity Al causes very little corrosion of the Mg alloy AZ31B in 3% NaCl soln. The results of addn. of Mg, Si, Mn, Fe, Cu, Ni, and Zn to the Al are given. It is shown that the presence of Mg ions in the corrosive medium greatly reduces the effects of any

(*Continued on page 86 P&R*)

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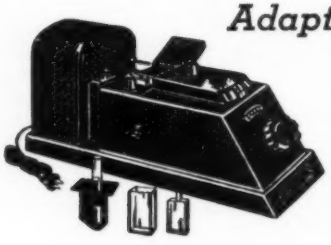

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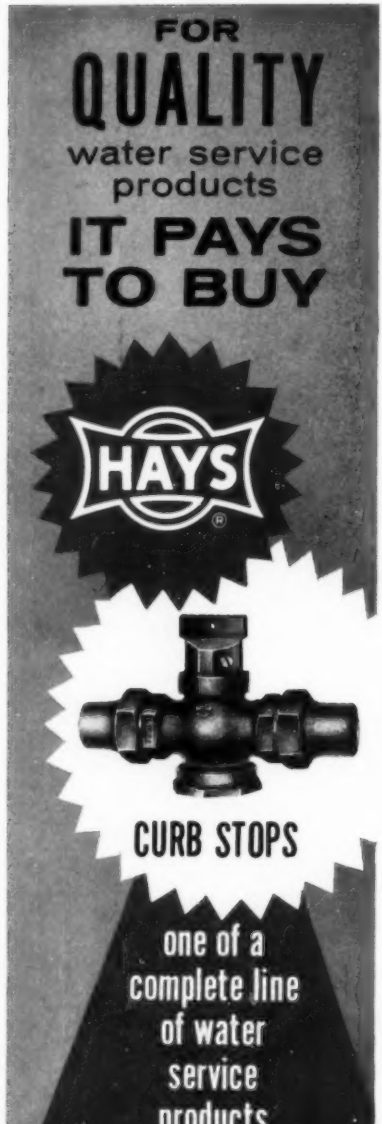

(*Continued from page 84 P&R*)

of the above addn. The cladding of Mg alloy AZ31A with 99.99% Al greatly improves its corrosion resistance to saline media.—*IM*

The Internal Cathodic Protection of Large Steel Pipes Carrying Sea Water. JOHN H. MORGAN. *Corrosion*, 15:417t ('59). The internal cathodic protection of large steel pipe carrying sea water is discussed both from the practical and the theoretical viewpoint. Systems considered involved use of such devices as concentric cylindrical anodes, off-center cylindrical anodes, wall-mounted anodes, and central point Pb alloy anodes fed with impressed current from a dc source. The cathodic protection was applied to both bare and coated pipe; testing was carried out both on a lab. scale and on a full scale level. The design of a potential measuring device and the detn. of protection criteria are briefly considered, as well as coating the pipe interior, calcg. the costs of cathodic protection, and detn. of the relations between anode sepn. and anode diam. in pipes with the same coating and anode electrolyte. Coatings will effect the largest economies on the smaller diam. pipe where the cost of the cable is lowest and where small anode supports can be used with small anodes. At this time, the most economical method of protection appears to involve the use of a cheap, readily applied coating of reasonable resistance and cathodic protection from point electrodes mounted at or close to the center line of the pipe.—*CA*

Corrosion of Paper Dryers Due to Industrial Water and Methods of Prevention. N. AWA & Y. YAMAMATO. *Nippon Daiyaku Kogaku Kenkyusho Iho* (Jap.), 16:272 ('57). The corrosion of Fe plate immersed in industrial, distd., well, and city water was examd. The Fe plate immersed in industrial water was corroded very rapidly, this corrosion rate being approx. twice that in distd., well, or city water. The reason for this fact is that the quantities of such salts as sulfates, NH_3, nitrates, and chlorides, etc., which are contained in industrial water, are 2–10 times more than those in well water. It is thought to be preferable, therefore, to adopt the cathodic protection making use of electrolytes in industrial water and the inhibitor-additive method for corrosion proofing. An Fe plate immersed in industrial water could be protected against corrosion

(*Continued on page 88 P&R*)

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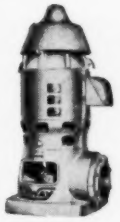

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(Continued from page 86 P&R)

by the application of cathodic protection, because the amts. of electrolytes present in industrial water are enough to use this method. The Fe plate is well protected merely by connecting a circuit with a Zn plate whose surface area is $\frac{1}{8}\frac{1}{0}$–$\frac{1}{8}\frac{1}{0}$ of the Fe-plate area. The corrosion of it is also protected by adding soap water of 0.1–0.2% to industrial water. The anticorrosion effect of the Fe plate is not reduced very much, even when the soap water is dried out into soap films. An Fe plate covered with paper contg. 60% industrial water could be protected against corrosion by making up a circuit with a Zn plate which is put in the paper and whose surface area is $\frac{1}{8}\frac{1}{0}$–$\frac{1}{1}\frac{1}{0}$ of the Fe plate. The surface area of the Zn plate should be varied in accordance with the absorption ratio of the paper. The joint use of soap water and cathodic protection produces the following effects: corrosion-proof by soap film and the state of distribution of Zn particles. Then, the utilization of Zn as an anode for the cathodic protection makes the paper white and smooth in texture.—*CA*

OTHER ARTICLES NOTED

Recent articles of interest appearing in periodicals of the water supply field are listed below.

"How is Your Manganese?" M. E. FLENTJE. *Wtr. Wks. Eng.*, 113:288 (1960).

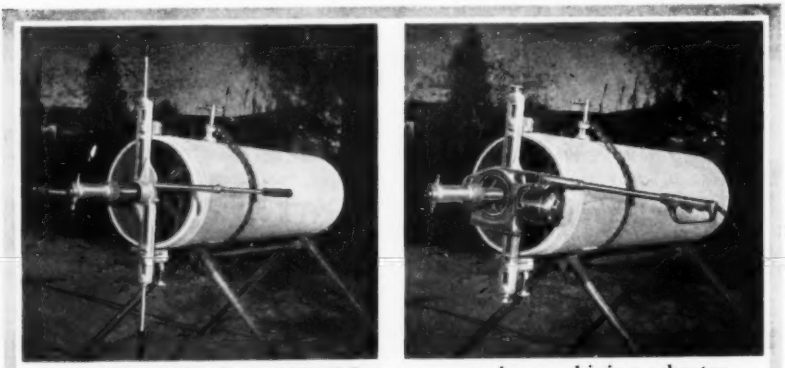
"Modern Trends in Sea Water Conversion." J. J. CAMPOBASSO. *J. NEWWA*, 74:1 (1960).

"Practical Corrosion Testing." W. E. KIRKENDALL. *Wtr. & Sew. Wks.*, 107:155 (1960).

"Use of Butterfly Valves on Water Distribution Systems." A. E. HATCH JR. *J. NEWWA*, 74:22 (1960).

"Will Treatment Plant Processes Remove Radioactivity in Water?" R. L. CULP. *Wtr. Wks. Eng.*, 113:296 (1960).

"Soluble Iron." M. U. PREISTER. *Am. City*, 75:5:123 (1960).



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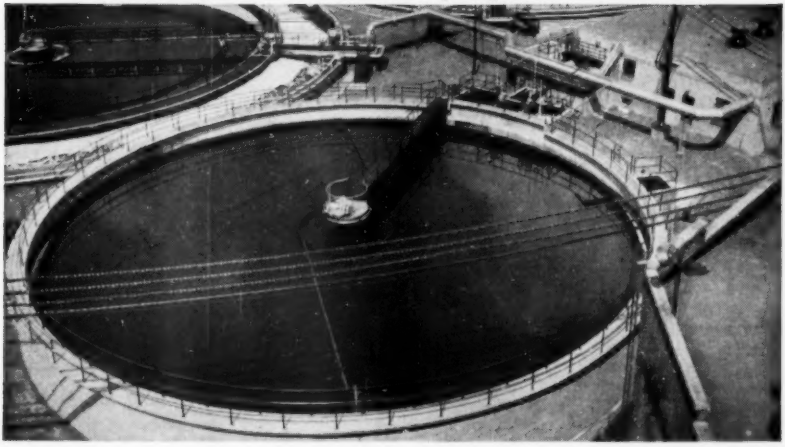

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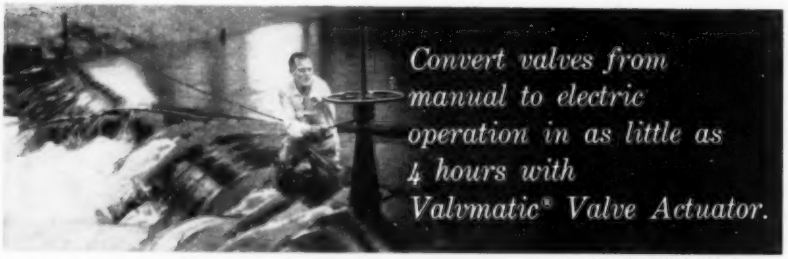

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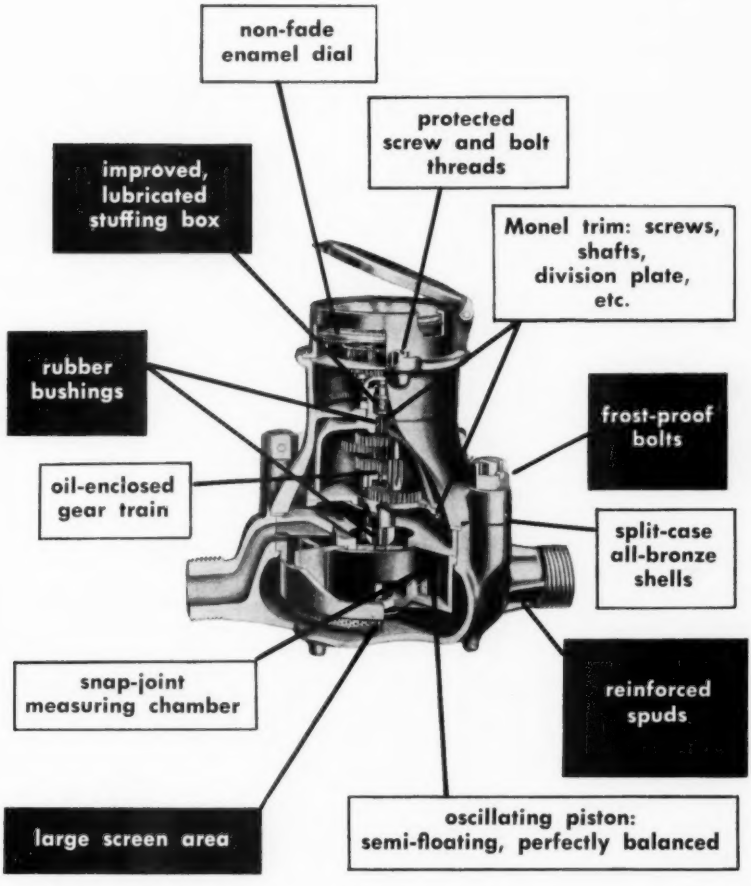

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A. P. Smith Mfg. Co.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators; see Locators, Pipe

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Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
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Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
DeLaval Steam Turbine Co.

Pumps, Centrifugal:
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American Well Works
DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Chemical Feed:
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Fischer & Porter Co.
Precision Chemical Pump Corp.
Wallace & Tiernan Inc.

Pumps, Deep Well:
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Fiese & Firstenberger
Layne & Bowler, Inc.
Peerless Pump Div.

Pumps, Diaphragm:
Dorr-Oliver Inc.
Wallace & Tiernan Inc.

Pumps, Hydrant:
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Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Peerless Pump Div.
Ross Valve Mfg. Co.

Pumps, Sewage:
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DeLaval Steam Turbine Co.
Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Sump:
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Peerless Pump Div.
C. H. Wheeler Mfg. Co.

Pumps, Turbine:
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Layne & Bowler, Inc.
Peerless Pump Div.

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Permutit Co.
Wallace & Tiernan Inc.

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Simplex Valve & Meter Co.
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Chicago Bridge & Iron Co.
Graver Tank & Mfg. Co.
Pittsburgh-Des Moines Steel Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
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M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
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Sludge Blanket Equipment:
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Infilco Inc.
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Sodium Fluoride:
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Calgon Co.

Sodium Hypochlorite:
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Sodium Silicofluoride:
American Agricultural Chemical Co.
Tennessee Corp.

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General Filter Co.
Hungerford & Terry, Inc.
Permutit Co.
Roberts Filter Mfg. Co.
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General Filter Co.
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Mueller Co.
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Rockwell Mfg. Co.
A. P. Smith Mfg. Co.
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Golden-Anderson Valve Specialty Co.
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Rockwell Mfg. Co.
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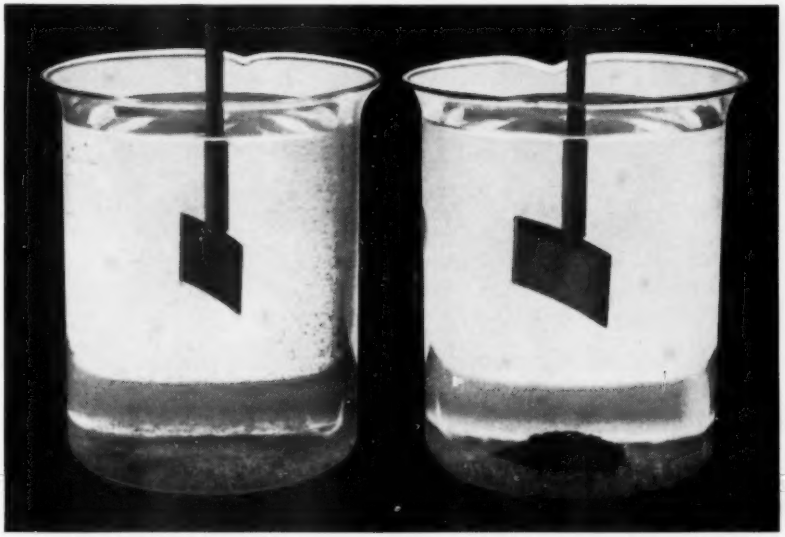

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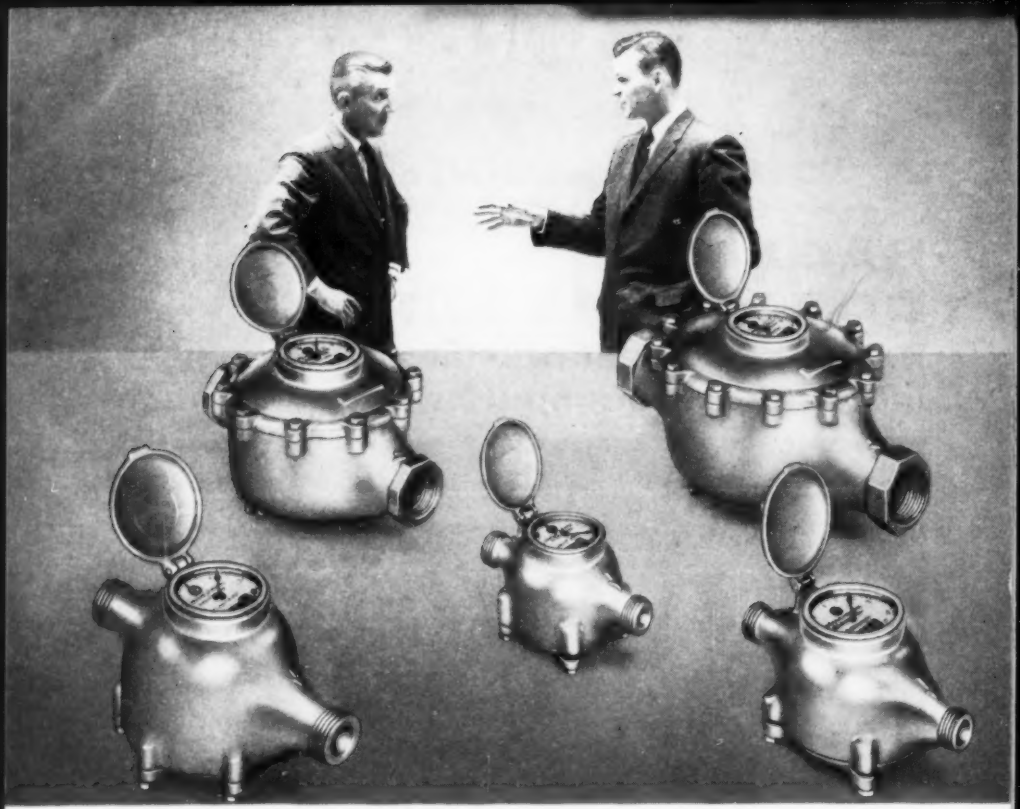

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